October 1955

NUCLEONICS

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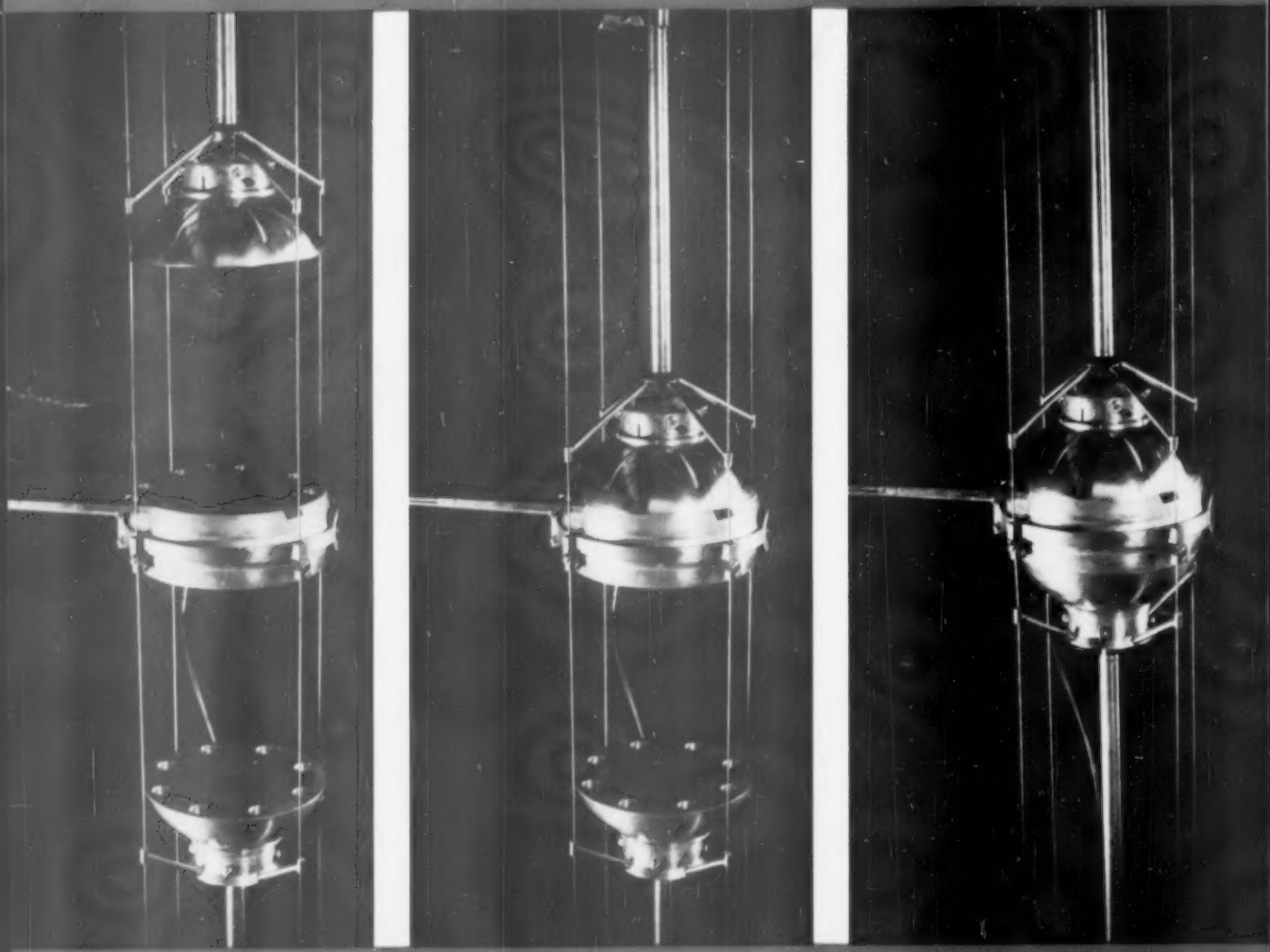

1—SAFE 2—HALF ASSEMBLED 3—CRITICAL

BARE PLUTONIUM SPHERE . . .

. . . Newest of the Critical Assemblies at Los Alamos — page 48

This CVC thermocouple vacuum gauge

offers high sensitivity and rapid response *at lower cost*

This single-stage thermocouple vacuum gauge gives rapid readings in the 1 to 1,000 micron range. It is the *CVC* type TG-029, designed around a printed circuit.

The gauge is compact, portable and priced considerably lower than the previous single-station model.

Its outstanding features include:

- No compensating adjustments—just plug it into a 115-volt outlet and turn on the power switch.
- Measures the total pressure of condensable vapors and permanent gases.
- Is not harmed by exposure to atmospheric pressure.
- One direct reading meter scale covers the range from 1 to 1,000 microns Hg.

New, more rugged gauge tube

This gauge uses the new TG-77 gauge tube which eliminates the fragile junction weld of previous tubes.

The tube is less subject to organic vapor contamination and its electrical characteristics do not vary appreciably from one tube to another.

The TG-029 is the latest addition to a complete line of *CVC* thermocouple gauges including the *battery-operated*, single-station unit type TG-025; the *one-to-six* station unit type TG-09; and the *automatic control* unit type TG-010 which actuates a double-pole, double-throw relay at any predetermined pressure.

Specifications

Range	1 to 1000 microns
Case Dimensions	$5\frac{5}{16}$″ x $6\frac{1}{16}$″ x $6\frac{1}{16}$″
Weight	5 lb. 14 oz.
Power	115 V. 60 cycle, AC
Type TG-77 Tube	$2\frac{1}{16}$″ with $\frac{1}{8}$″ NPT nipple
Cord	10 ft.

TG-09—One-to-six station unit. Measures system's pressure at several locations.

TG-010—Single-station unit with automatic control for auxiliary circuits.

For information on these and other *CVC* vacuum measuring gauges, write to ***Consolidated Vacuum Corporation, Rochester 3, N. Y.***

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NUCLEONICS

OCTOBER • 1955

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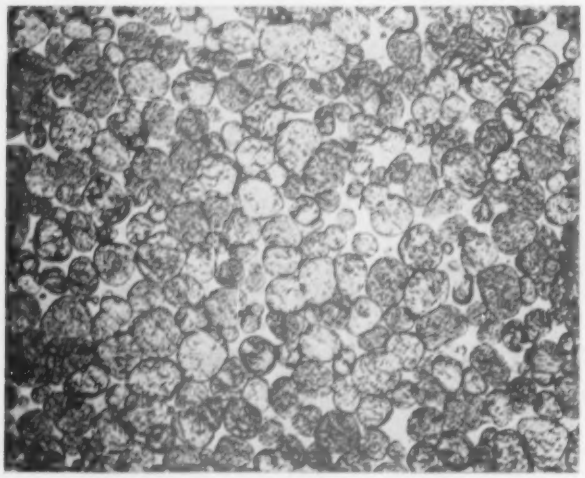
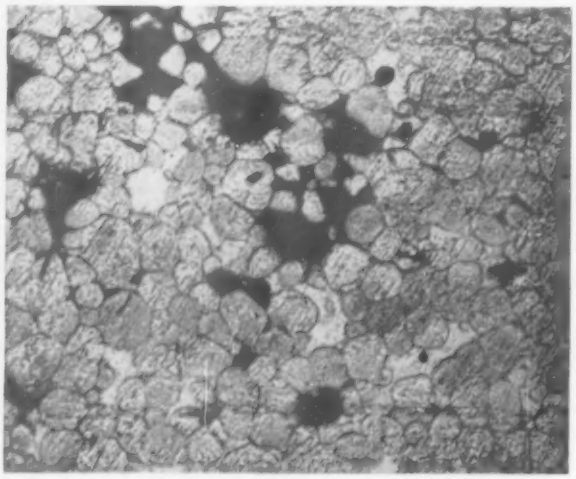
Uniform Structure

of Mallory 1000 Metal assures effective radiation shielding



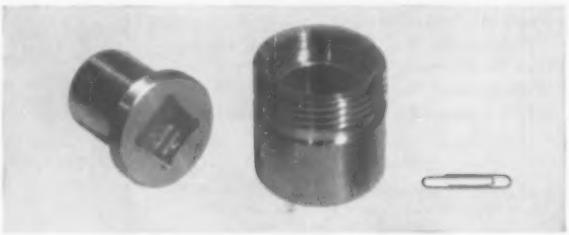
Mallory 1000 Metal, under high magnification, shows completely uniform grain structure. Its high density extends through every part of the piece . . . free from voids and weak spots.



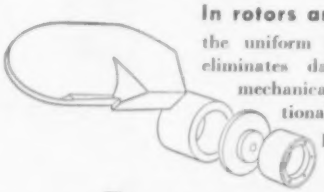
Voids in less uniform metals look like this under the microscope. They seriously impair shielding effectiveness and tend to make performance unpredictable.

WHEN you design radiation shields with Mallory 1000 Metal, you can figure on the basis of *accurate* characteristics . . . instead of having to estimate on "typical" values. You can predict performance of your design precisely, because every piece of Mallory 1000 is produced to the same, precisely controlled qualities . . . and, most important, these qualities are completely uniform *throughout each piece* of the metal.

Up to 40% more effective than lead, Mallory 1000 is being used for shielding at energy levels up to 100 MEV. It has excellent weathering qualities, and machines to a high surface finish. Intricate shapes are produced economically to accurate tolerances by exclusive Mallory contour pressing methods. For complete data, write to Mallory for Technical Bulletin 6-7.



Typical source capsules made of Mallory 1000 provide "leakproof" shielding.



In rotors and counterweights, the uniform structure of Mallory 1000 eliminates danger of unbalance. High mechanical strength, density and rotational inertia make possible smaller parts, faster rotational speeds.

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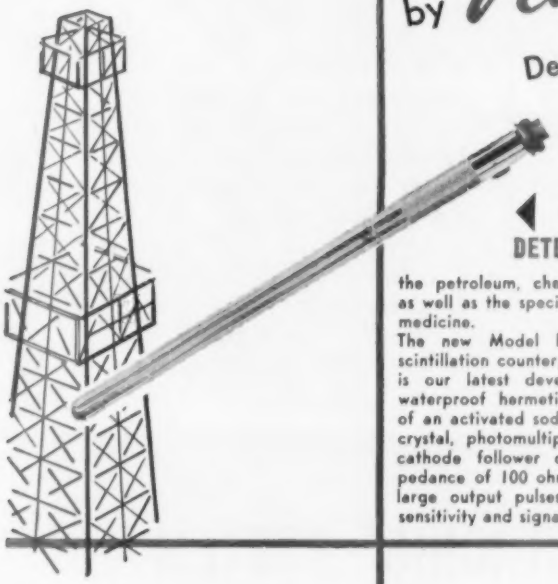

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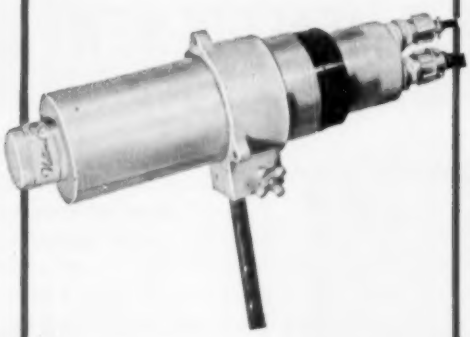
Easily adapted with Collimator Attachment, Well Type Shield or Sample Changer, the National Radiac Scintillation Counters fill the outstanding need when highly directional detection, extreme sensitivity and low background signal to noise ratio is required for research, medical or industrial use.



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The National Radiac 3" and 5" diameter complete scintillation counters are used for the most exacting applications in industry, research and Aerial Scintillation Surveys. They are completely versatile and can be quickly adapted for collimator applications, well type sample analysers and manual sample changers. The complete standard scintillation counter consists of a radiation detection crystal, photomultiplifier tube, and either the preamplifier or cathode follower. These scintillation counters are of the highest known sensitivity. Ready now for immediate delivery.

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Write for Bulletin #13 containing complete information and specifications. Personal consultation is available at no cost by contacting our research department.

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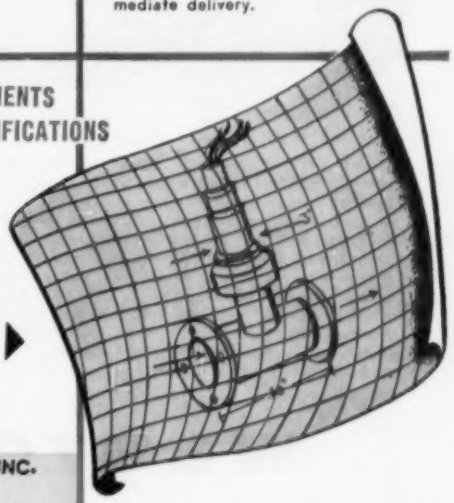
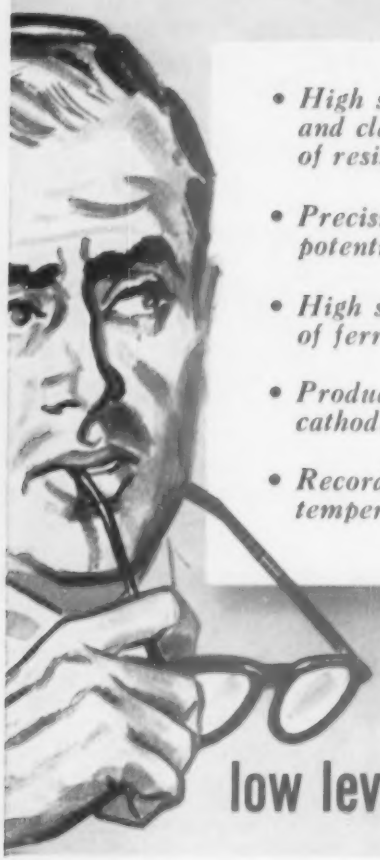


National Radiac INC.

479 WASHINGTON STREET, DEPT. N, NEWARK, NEW JERSEY

These or similar problems puzzling you?



- *High speed inspection and classification of resistive elements*
- *Precision control of minute potentials and currents*
- *High speed inspection of ferromagnetic materials*
- *Production testing of cathode ray tube brightness*
- *Recording extremely low temperature differentials.*
- *Continuously recording rate of temperature change in jet engine test stands*
- *R.M.S. regulation of a-c oscillators and generators*
- *Multiplication of two a-c or d-c signals to provide a precision product*
- *Precision low power factor measurements for production inspection of transformers and motors*

The INDUCTRONIC® SYSTEM of low level MEASUREMENT and CONTROL

Model 1475 Multi-Range Inductronic D-C Amplifier provides amplification of a complete span of direct current and voltage ranges of either polarity with no sacrifice in fundamental accuracy or speed. Has seven current ranges, from 10 to 1,000 microamperes — and ten voltage ranges, from 1 to 1,000 millivolts. All ranges immediately available by the turning of a switch; and an additional seventeen ranges become available by a knob adjustment which changes the instrument from zero left to zero center. Accuracy 1%. Accessories such as recorders and additional indicators can be inserted in the output to a total of 5,000 ohms without affecting accuracy or calibration.

Practical solutions to the above, and many other problems of low-level measurement and control have been supplied by the WESTON Inductronic System . . . an entirely *different* method of d-c amplification. Utilizing the deflection of a permanent magnet moving coil system, it converts extremely low-level d-c to a proportionate a-c signal and amplifies it to a *usable degree* . . . then reconverts to a d-c level. The system operates at a frequency of 200 KC, and provides a high order of sensitivity, accuracy and speed. And because of circuit simplicity, the system is stable and virtually maintenance free. To learn how you can apply the Inductronic System in research or production, call your nearest Weston representative, or write direct for bulletin B-36-B.

WESTON *Instruments*

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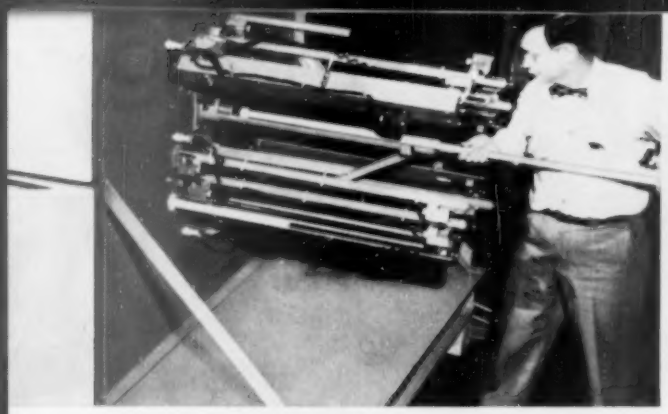
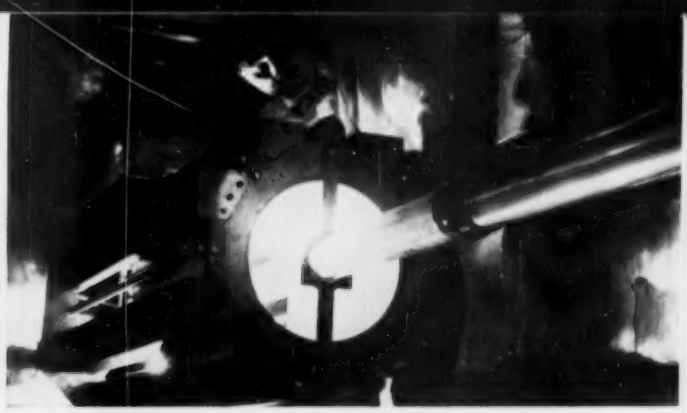


Reactor Control Rods



Reactor Core

Control Console for Reactor System

Electromagnetic Pump

Components for atomic reactor systems now available from General Electric

REACTOR CONTROLS

- preamplifiers
- power level amplifiers
- control rods
- rod drives
- control consoles

REMOTE HANDLING EQUIPMENT

- manipulators
- optical systems
- inspection stations
- transfer dollies
- charging devices

COOLANT SYSTEM COMPONENTS

- electromagnetic pumps for sodium or molten metals
- special mechanical pumps
- stop and check valves
- freeze seals
- electromagnetic flowmeters

REACTOR SERVICE EQUIPMENT

- refueling, servicing, and maintenance equipment
- storage equipment
- fuel element record system

These components, now available from General Electric, are used in atomic reactor systems by utility, industrial, research, and educational organizations. General Electric also designs and manufactures complete nuclear reactor systems (less fissionable material). The use of the reactors will be governed by the Atomic Energy Act of 1954.

FOR SPECIFIC INFORMATION on any of these components for atomic reactor systems, contact your General Electric Apparatus Sales Office or write to: General Electric Company, Section 224-7, Schenectady 5, N.Y. Send coupon below for new bulletin on G-E Components and Services for Nuclear Reactor Systems.

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Semiautomatic production line for manufacturing and cladding fuel elements at Sylvania's Hicksville, N. Y., plant.

Cutaway showing canned fuel element with high-integrity bond (1.5 times actual size).

Inside story of nuclear fuel

THE attainment of economically generated atomic power demands effective performance from the nuclear fuel elements employed. Such a fuel must be capable of high-temperature operation for an extended period of time and some of its important attributes are—

❶ A strong, continuous bond must be present between the metal casing and the core of active material (see illustration above). Voids or discontinuities in the bond may cause hot spots and the premature destruction of the fuel element.

❷ The active core material and casing must be of a physical construction that will withstand incessant bombardment within the reactor—yet allow heat to flow readily and uniformly to the coolant stream.

❸ The bond between casing and end cap must be so complete as to prevent seepage of the coolant into the element core—and the escape of fission products from core to coolant stream.

Techniques for insuring these as well as many other important qualities have been perfected through Sylvania's specializing fuel element research and production facilities. Sylvania's scientists and engineers—pioneers in the development of high, long burn-up fuel—are ready now to help you design fuel economy and reliability into your power production or experimental reactor.

For detailed information, including a newly-published brochure on Sylvania's nuclear energy design and production facilities—write Sylvania Electric Products Inc., Atomic Energy Division, P. O. Box 59, Dept. K55V, Bayside, New York.

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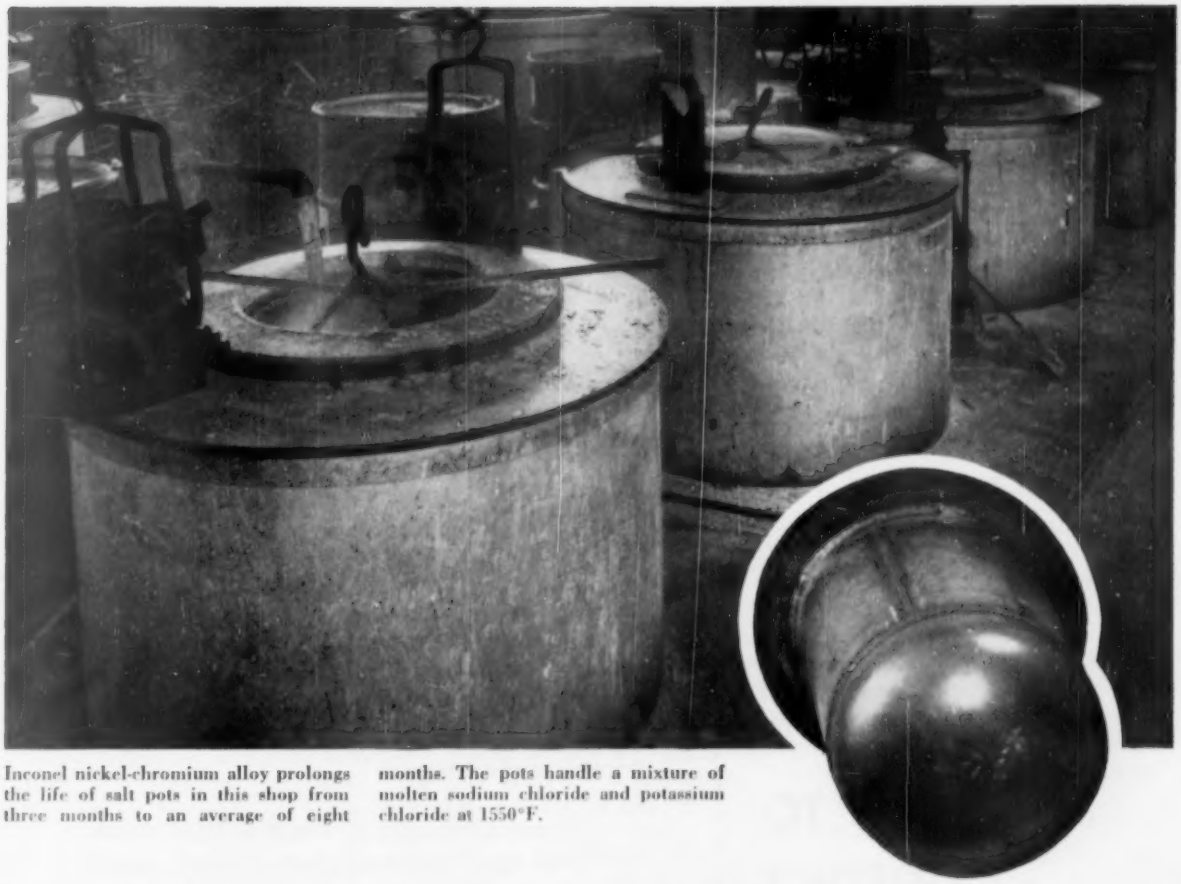

Inconel nickel-chromium alloy prolongs the life of salt pots in this shop from three months to an average of eight months. The pots handle a mixture of molten sodium chloride and potassium chloride at 1550°F.

Inconel Salt Pots last up to 8000 hours at 1550°F

Here's an alloy that takes molten salts in stride.

Here . . . where a sodium chloride-potassium chloride mixture is used at 1550°F to harden oil field drilling tools . . . Inconel* nickel-chromium alloy prolongs the life of salt pots several-fold. Average life of pots was formerly three months. Now, it's eight months on the average, and in some shops as much as eighteen months of life has been recorded.

In other applications, such as Nicrobrazing retorts . . . annealing furnaces . . . jet aircraft engines . . . chemical and petrochemical pyrolysis furnaces . . . Inconel alloy withstands temperatures up to 2150°F over hundreds of cycles even in the presence of hydrogen and other destructive gases.

Useful in atomic energy field

Inconel nickel-chromium alloy also meets four basic demands of atomic energy equipment.

1. Inconel is structurally stable. It is not subject to embrittlement on prolonged heating.

2. Inconel is chemically stable. It resists damage by oxidation, carburization and other forms of high temperature attack.

3. Inconel is mechanically stable. It retains useful properties to 2100°F and over, in some applications. It resists grain growth and withstands thermal shock.

4. Inconel is easy-to-work . . . easy to form, machine, weld . . . available in all commercial wrought forms.

Get the facts about Inconel alloy

Information about properties, fabrication and forms of this heat-and-corrosion resisting alloy are yours for the asking. Write for Inco's 24-page Technical Bulletin T-7 "Engineering Properties of Inconel."

Ready help on metal selection problems for high-temperature equipment is also yours for the asking. Send details to Inco's Technical Service Section. We'll be glad to give you a hand.

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To insure the utility of these tests, *NDA* has designed and operated systems which accurately control and record in-pile test conditions. The heart of *NDA*'s system is a test capsule containing the material to be tested, a heater for accurate temperature control and monitors for determining the integrated neutron flux. This capsule is suitable for operation at temperatures up to 1800° F. in the highest neutron fluxes available in this country.

NDA offers a "package" irradiation service which includes design and construction of the in-pile test system, supervision of the irradiation test at the reactor site selected by the client, and transportation of the test sample in a shielded container to the analytical laboratory for post-irradiation examination.

Consultation on a program to meet your specific testing requirements is available without obligation.

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80 GRAND STREET, WHITE PLAINS, NEW YORK

ROUNDUP of Key Developments in Atomic Energy

LATE NEWS and Commentary

Fusion Reactors —When?

At a Geneva-promised press conference, AEC chairman Lewis L. Strauss reconfirmed in Washington on Oct. 3 that the U. S. does have a program aimed at developing controlled thermonuclear power plants. But he said little more than his Geneva statement: "The Commission is and has been working on the subject for a considerable time." In fact what may be the most positive statement is contained in a "help wanted" ad for an electrical engineer on p. 106 of this issue: "An exciting opportunity exists in new classified research field of great peacetime significance."

AEC gives no real indication of what work is being done, or even what the detailed technical problems are. Such information is still secret, and is made available to a very small number of people within the AEC project on a highly compartmentalized basis. Industrial nuclear power groups are said not to have access to these reports, and the only way industry gets into the picture is via loan of a few people to the scattered work being done.

A general comment on the nature of the problem was made by Lyman Spitzer, Jr., director of the Princeton University Project Matterhorn, an important part of the over-all Project Sherwood: "We must achieve such temperatures (over a hundred million degrees F) in a gas confined in walls that remain relatively cool. We must control the thermonuclear reaction when it occurs. We must extract the energy released and use it to generate electricity."

In addition to Princeton, work is going on at: ORNL, under E. D. Shipley, John S. Luce and Albert Simon; NYU, under Robert D. Richtmyer and E. Bromberg; at Livermore, under Herbert F. York; and Los Alamos, under J. L. Tuck.

•

AEC Authorizes Foreign Business

After much prodding from U. S. industry and admitting that its earlier policy "is believed to have a discouraging effect upon American industry and its potential customers abroad," AEC announced on Oct. 3 that companies wanting to engage in unclassified foreign nuclear activities need no longer clear with AEC before doing so. However, they will have to report back to AEC afterwards. This announcement, placed in the Federal Register, is the long-awaited interpretation of Sec. 57a(3) of the Atomic Energy Act.

•

Foreign Business Problems Pinpointed

How to do business abroad highlighted discussions at last month's Atomic Industrial Forum meeting (sponsored in part by American Nuclear Society). Sellers, customers and governments are faced with many knotty problems.

Representing the sellers, F. K. McCune of General Electric said: Before U. S. companies can follow through on the many foreign sales prospects they now have, they must get clearcut policy statement from AEC on if, when and how nuclear fuel will be made available for export for power-reactor use. Because "almost any major country" can now produce plutonium from available knowledge, he feels controlling international use of special nuclear material is now impossible and that U. S. would be wise to offer foreign assistance on fuel. He suggests as maximum action putting enriched fuel on sale domestically, for domestic or foreign use, with normal export-license control.

Speaking as a customer, Giorgio Valerio, managing director, Societa Edison, Italy, emphasized the dependence of Italy on "the assurance of a 'free' and continuously increasing supply of nuclear fuel." He said that unless a supply of special nuclear material was guaranteed for every plant sold for a "sufficient

length of time to make the plant economically sound . . . we would be compelled to develop a program like that of the British based exclusively on natural uranium." To indicate the immediacy of the problem, he said several large Italian companies are already "negotiating the purchase of power reactors . . . Fiat, said to have purchased a 10 Mw plant; Edison, negotiating a 80–100 Mw plant; La Centrale, considering a similar plant; Montecatini believed to be discussing a materials testing reactor."

Recognizing the problems of dependency on other nations, France is developing what it feels is a self-sufficient program via the natural uranium-plutonium route. In the next three years, they say they will have enough uranium and thorium to cover all their presently planned needs and that Madagascar thorium will make France the world leader in its supply. Although they are studying building a gaseous diffusion plant, the final decision will await developments in international cooperative efforts on uranium-235 supply.

Canada, one of the big-three uranium suppliers, feels that because of its success with natural uranium reactors and because customers will not want to tie themselves down to being dependent on uncertain U-235 supplies there will be an important export market for its U-238 and U-238-fueled reactors, as for example the duplicate of its NRX that is being sent to India.

NUCLEONICS has learned that the U. S. has reached a decision to make nuclear fuel available for export for power reactors and that an announcement on this will be forthcoming shortly.

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Operation of Inspection Division

AEC's new Inspection Division will, according to its director, Curtis A. Nelson, divide its checking of reactor installations into three parts: construction, startup and annual visits during operation. Periodic visits will be made during construction to check such things as: fabrication and installation of control and safety systems, instrumentation, fabrication of fuel elements, shielding construction and containment measures. Then the division staff will witness testing of equipment through dummy running, loading with live fuel elements, and the initial run to criticality.

To be covered in a typical inspection of a reactor in operation will be: dynamics of the reactor; control system; safety system; instrumentation; personnel; operating and emergency procedures; safety factors; and radiation protection provisions. An installation will also be visited when a "significant increase" of power level is planned.

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Reactor Assistance

Ever since the U. S. announced in June that it would underwrite half the cost of foreign research reactors, both manufacturers and customers have been trying to learn just what this would cover and what arrangements would be necessary. One U. S. firm even says its customers have been delaying completing deals until clarification could be obtained. Now AEC states that "the Commission, the Department of State and other agencies are working out the methods for providing this assistance" and that industry will be "informed of these as soon as possible to assist your prospective customers in planning their reactor programs."

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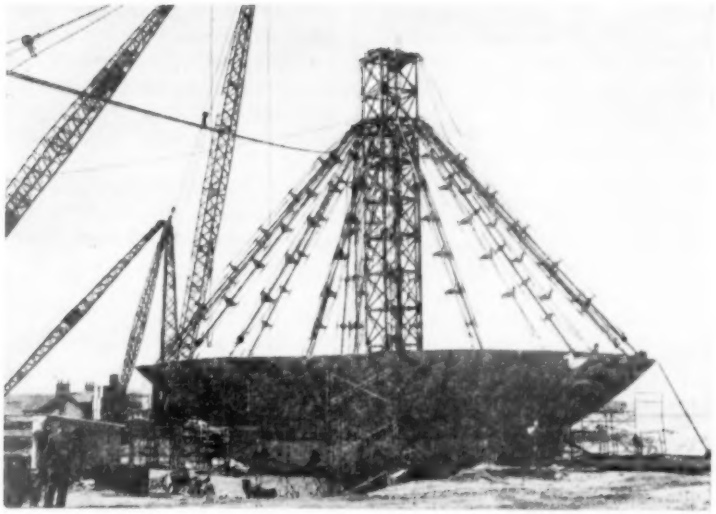
Fuel Business

AEC wants to get out of one part of the nuclear fuel element fabrication business—the making of MTR-type elements at Oak Ridge National Laboratory. Industry has been invited to submit bids on producing a one-year supply of such elements for AEC's use. Twelve firms are said to have bid. The winner will undoubtedly gain an advantage in competition for the many foreign reactors that will use this type element.



CONTAINMENT SPHERE for Britain's fast breeder reactor is being built on site at Dounreay, Scotland (NU, Sept. '55, pp. 48, 112). Sphere will be 135 ft in diameter; of 1-in. steel plate, it can contain internal pressure of 18 psi

Classification On Way Out, Says AEC's Libby

Atoms-for-peace conference in Geneva presages the "denouement of atomic classification," says Dr. Willard Frank Libby, member of the Atomic Energy Commission and a leading delegate to the conference.

"It's no longer worth the trouble to carry on education on a classified basis. The fundamentals are all out in the open." These comments were made in an interview with NUCLEONICS following Libby's return to Washington. The AEC member believes that any individual with an ordinary technical library at his disposal and a complete set of papers presented at the conference can be "in business" as far as nuclear power is concerned.

Libby is satisfied that the wealth of data unveiled at Geneva clearly demonstrates the dividends to be derived from sharing nuclear information. "Even disregarding atomic power," he said, "the effort has been well worthwhile. I found more on isotopes than I had expected."

Questions on other topics brought these reactions:

• The Russians are first-rate scientists, said Libby. None of those he saw at the conference would have trouble finding high-level jobs in this country; they're comparable with our own. This pleases Libby the scientist, but disturbs him as an AEC official. He had half hoped to discover the Russians were novices.

• British technology and development does not lead the United States in any field, says Libby. He's inclined to think they have heavily loaded their single basket. As a chemist, he leans toward the homogeneous reactor.

• The diversified U. S. reactor development program will pay off in the long run, both as to domestic and as to foreign requirements, Libby believes.

• American businessmen may be ignoring a good bet in certain phases of the radiation instrument field according to Libby. He also chides them for ignoring his favorite subject, the carbon atom. As he is discoverer of radiocarbon dating, he speaks with considerable feeling.

Among the things that distressed him at the Geneva conference was the apparent lack of American initiative in turning out more counters tailored to soft beta rays and low-level use. He foresees expanding medical and industrial markets for them.

He notes that every single organic compound can be uniquely identified through carbon and hydrogen, and simply can't understand the lack of demand for sensitive counting instruments. One gets the impression that Libby is not sure where the fault lies. It may be with the medical and industrial experimenters. It may be with the instrument manufacturers and suppliers. In either case, he believes the lag is hampering the accumulation of scientific knowledge.

AEC Offers Incentives For Smaller Reactors

Atomic Energy Commission's new program for spurring development of smaller power reactors will have these effects: 1) to quiet criticism from public power groups that the previous program was tailored for large electric utilities. 2) to encourage export of reactors by encouraging the low-power types suitable for underdeveloped areas.

AEC has invited proposals for nuclear power plants with the following electrical capacities: 5–10 Mw, 10–20 Mw, and 20–40 Mw. Plants must be located within the U. S. including its territories, possessions, and the Canal Zone. Closing date for proposals is February 1, 1956. This is the second invitation issued under the Power Demonstration program.

Incentives in the new program are more liberal than for the previous one. In the new one AEC will consider complete financing of the reactor system. It will waive for up to five years all or part of the regular charge for nuclear material. Further, the agency proposes to furnish research facilities and bear part of the cost of development.

All types of organizations and groups, manufacturers and utilities, are invited to submit plans and proposals for participating in the new program. Participants will be chosen on the basis of the technological promise of their design. This will include fuel economy, safety, ease of operation and other factors. Special consideration will be given to designs which require 10% or less enrichment of U^{235}.

By offering to pick up much or all of the price tab, the new program should appeal to the small utilities and rural electric cooperatives that haven't been able to afford to get in on nuclear development work. However, even the expense of a small technical staff for such development is prohibitive to most individual co-ops. More likely they will work through their National Rural Electric Cooperative Association, which already has cleared personnel for such work.

These two features, too, make the program look good to men interested in reactor export, either for diplomatic or commercial gain. Foreign countries, especially those underdeveloped, have a keener interest in the smaller reactors than in the large 150–200-Mw sizes that were proposed under the previous develop-

ment program. Because enriched fuel is expensive and obtainable from few countries, the fuel-economy promise of the new program bids fair for the export trade.

Russian Bilaterals; Iron Curtain Action

Russia's calm discussion of atoms-for-peace actions behind the iron curtain gave no more than a hint of the feverish activities that must have preceded Geneva. Until June of this year, the nuclear program in the Communist orbit was a one-nation show. Satellites furnished material, equipment, and possibly manpower, but all major research was carried out in Russia.

At Geneva, Russian spokesman A. N. Lavrishchev reported that bilateral agreements had been signed with Poland, Czechoslovakia, Rumania, Hungary, Bulgaria, and Communist China. These bilaterals followed close on the heels of visits to Russia by satellite scientists and officials, during the period March through June of this year.

Under these agreements, Russia promised to furnish at cost 2,000-kw multipurpose research reactors and cyclotrons to the leading Communist countries, and a 6,500–10,000 kw heavy water reactor to Communist China.

From Vienna, McGraw-Hill World News sends in this rundown of nuclear developments behind the Iron Curtain:

East Germany. Under direction of the Russian-dominated Ministry of

Reactor News

France getting fuel from Britain for new Saclay reactor. France is getting 1.4%-enriched U^{235} from Britain for its new Saclay reactor. For its dual-purpose reactors at Marcoule, France is using magnesium-alloy cans for fuel elements. Fins on elements are gear shaped with about 20–25 teeth. The magnesium alloy includes 1% zinc and 0.7% zirconium. Fuel can be run up to 400° C.

Core vessel delivered for HRT. On September 16th, Newport News Shipbuilding and Drydock Co. delivered the reactor vessel assembly for ORNL's Homogeneous Reactor Test (NU, June, '55, p. 41). Reactor shield pit is finished. Operation is planned for early next year.

NRX operates again. After a 7-week shutdown to decontaminate the core tank after an experimental fuel rod burst, Canada's NRX reactor is operating again (NU, Sept. '55, p. 109). Removal of small chips of plutonium adhering to the tank bottom involved flushing 6,000 gallons of sodium bicarbonate solution through the tank. Fresh D_2O is now being used; the old D_2O will be decontaminated and used in NRU next June.

Canada to furnish India NRX-type reactor. India has accepted Canada's offer of an NRX-type experimental reactor valued at about $24-million. While a bilateral agreement is being worked out, the Canadian government will ask Parliament to appropriate funds for the project, which is part of the Colombo plan . . . Also, the Indian AEC discloses that another reactor (apart from the swimming-pool type to be built at Trombay) will be set up near Bombay with U. S. technical assistance. Reports from India indicate an expectancy that H. J. Bhabha's Russian trip also will produce an offer.

AEC plans to order more zirconium and hafnium. Next month, AEC expects to invite proposals by February for delivery of reactor-grade zirconium metal at the rate of 2-million pounds over five years or 1.2-million pounds over three years. Deliveries probably must start by July, 1957; hafnium metal produced from the Zr processed is to be included. These new needs are in addition to those of privately financed nuclear projects. AEC also has a contract with Carborundum Metals Co., Akron, N. Y., for 200,000 lbs of Zr and 4,000 lbs of Hf per year.

NACA to build $4.5-million test reactor in Ohio. To test both airframe and reactor-engine components in radiation fields, the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics plans to operate a reactor at the Army's Plum Brook Ordnance works near Sandusky, Ohio. Construction contracts will follow design completion near year end.

Reactor heat for chemical processes due for increased study. At the urging of chemical firms, AEC and the Interior Department's Bureau of Mines are planning a meeting to consider use of reactors as economical heat sources for chemical processes. However, since reactor-materials technology limits core temperatures of present and near-future reactors to the range of 1,000° F, widespread application seems some years off.

One such use, in which Bureau of Mines is keenly interested, would involve piping pressurized steam and powdered coal through a reactor core in a 2–10-sec pass to make synthesis gas (a mixture of H and CO useful in making a wide range of chemical products.) Since 2,000–3,000° F would be needed for good yield, problems center around materials for core and pipe.

But incentive is high for solving these problems because the coal burned and tonnage oxygen required in present process account for about half the 16¢/1,000-ft³ cost of raw synthesis gas. Silicon carbide is being considered for pipe material, but its permeability may limit its use at much above 15 psi.

ORNL to test centralized control room for LITR and X-10 Graphite Pile; may include ORR later. To learn feasibility of operating more than one reactor from a single control room, Oak Ridge National Laboratory is installing a set of controls for the Low Intensity Testing Reactor in the control room of the X-10 reactor. Parallel control for the LITR will be continued in its building. If experience indicates practicality of scheme, AEC's safeguards committee will be asked to approve shutdown of the console in LITR building. Later, Oak Ridge Research reactor (ORR) controls may be included. If practical, central control will reduce operating costs.

Internal Affairs, the Transformatoren und Roentgenwerke in Dresden is switching to production of nuclear equipment. The firm will deliver all nuclear equipment required for a small research center in Miesdorf, as well as an auxilary at Buch. Generators have been exported to Russia, Czechoslovakia, and China.

Czechoslovakia. The government is planning a nuclear program around the research reactor and cyclotron which Russia has promised to furnish. The Czech government, in a Ministers' Council, decided the location where the reactor and the accelerator are to be placed. The site, so far, has been kept secret. It was announced, however, that an institute of nuclear physics was created in Prague in July following on the heels of conferences with the Russians. In September, university courses were instituted to train nuclear engineers, scientists, and technicians. Czech industry also is studying the feasibility of a similar training program. Czech scientists and officials attended conferences with Russians in Moscow in July according to private news sources.

Hungary. A Hungarian scientist claims a new process for concentrating uranium. Prof. Sandor Szalay reports that uranium contained in coal is agglomerated by simply burning the coal. The uranium content of the ashes, he believes, are concentrated sufficiently to permit economic separation. Nuclear work is centered at Csilleberc, a few miles outside of Budapest. A 5-million-volt generator is nearing completion, machined and fabricated by the laboratory and Hungarian industry. Lajos Janossy, runaway English scientist, has been rumored to be playing a key role in the Hungarian program.

Poland. Taking its cue from Russian conferences, scientists have founded a "Polish Nuclear Academy of Science," and a "Committee for the Peaceful Application of Atomic Energy." Domestic-made 4-Mev Van de Graaff accelerator is under construction.

Professor Infeld, chief Polish delegate at the Geneva Conference and chairman of the new Committee stated that "for the first time since the close of World War II scientists can exchange ideas freely; the definition of science as international

Industrial Applications

Improved bonding of ink to polyethylene. Gamma irradiation, to a dose of 0.5 r or more, oxidizes the surface of polyethylene, changing its ink-retention properties from poor to excellent. Poor ink adhesion is a drawback in using polyethylene film for packaging. A treatment used is differentially heating the film in a flame. Advantages of new gamma-ray treatment are: both sides are made printable; the film can be treated in mill rolls, eliminating the winding-rewinding problem; and the treatment is uniform and consistent. Costs have not been established, but might be high compared to flame treatment. Nevertheless, one packaging producer is interested. Brookhaven researchers R. N. Chapman and P. Colombo are doing this work, using a cobalt-60 source.

Cyclotron-produced radioisotopes don't need AEC authorization. Nuclear Science and Engineering Corp., Pittsburgh, Pa. has inaugurated the first private program for production and supply of cyclotron-produced isotopes. Procurements do not require AEC approval. Radioisotopes will be produced by the U. of Pittsburgh's and other cyclotrons and processed by NSEC. These isotopes will no longer be supplied by AEC.

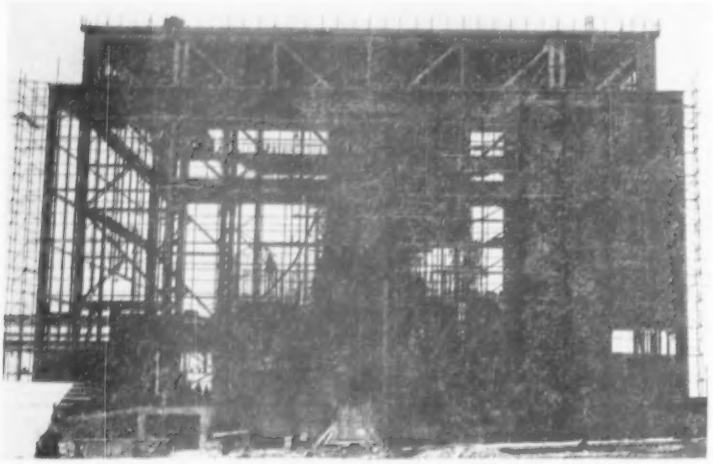
Radiation improves transistor performance. Even after a point-contact type germanium transistor is fabricated, its current-decay performance can be improved by reactor irradiation. Transistor specification for one use is that collector current fall from 15 ma to 2 ma within μsec after stopping emitter current. Typical result of irradiating a transistor to a dose of 10^{14} n/cm^2 is to bring it within specification, whereas before irradiation decay time was 10 μsec. Decreased decay time is caused by new recombination centers, such as lattice defects, within the material. Chemical and heat treatments during manufacture also can change carrier life-time, so irradiation treatment might be viewed as a supplemental quality-control method. Cooke-Yarborough and co-workers at AERE, Harwell, England, who devised irradiation method, report that about 90% of presently received transistors meet specification, and all the others are brought into tolerance by irradiation.

Simpler carbon labeling for wash testing—more accurate than reflection tests. Adsorption of Zr-Nb^{95} tracer by carbon is a better method for testing wash effectiveness than using irradiated C (where porosity and particle size become unknowns), and cheaper than using labeled tripalmatin ($625/mc). Reflectance tests don't always give valid results, because reflectance depends on size distribution of C, as well as amount; and size distribution is changed when detergent is added. A. K. Phansalkar and R. D. Vold, U. of Southern California, use this procedure to get 99% adhesion of tracer to the suspended C: ¼ or ½ wt % C suspension is prepared by stirring, then the desired detergent, sodium dodecyl sulfate, is added and stirred in. Next, 0.2–1.0 ml of diluted tracer solution (0.2 ml stock solution in 10 ml) is made slightly alkaline, added, and stirred. The cloth is soiled by one min of vertical agitation. Nonadherent C is then rinsed off. Difference between reflectivity and labeled-C testing runs as high as factor of 3, reports E. B. Ashcraft, Westinghouse Research Labs.

ROUNDUP

property has been re-established. The Polish team was among those scientists who followed the British invitation to visit Harwell."

Rumania. Committee for Nuclear Energy has been formed from the Rumanian Council of Ministers. It will supervise all matters related to atomic work. Rumania's nuclear role in the Communist orbit has been mainly to supply raw materials to Russia.



G-1 RISES AT MARCOULE in south of France near Rhone River. Built as power prototype, the 40-Mw (heat), air-cooled, plutonium-producing reactor is scheduled for completion in 1956. It is slated to produce 15 kg of Pu in 1957 (NU, May '55, p. 14)

AEC Rejects Co-op Bid

AEC turned down the proposal of the Rural Cooperative Power Association of Elk River, Minn., for a federally-aided 22,000-kw dual-cycle boiler. As in the cases of Yankee Electric and Consumers Public Power District, the way was still left open for revision of the unaccepted proposal. AEC said objections were technical, rather than financial. The fact is, however, that Elk River could not have been expected to know it was making a mistake in at least one specification—it asked that AEC manufacture its fuel elements; on the same day that the proposal was rejected, AEC issued a new announcement on its power demonstration reactor program stating that it would no longer fabricate elements.

Washington Report

Classification battle in Washington is taking on a new shape. With many areas of reactor technology opened up by the Geneva conference, there is some worry that trade secrets may be put in the public domain to the detriment of American manufacturers. The British are on record in favor of holding on to industrial secrets, and the program in that country adheres strictly to that policy.

The classification argument in this country has not been settled along the neat British lines. Secrecy for military reasons may be stretched to include world politics, of course. The cold war is no less an international conflict because neither side is firing a shot.

AEC has a perfect right to maintain tight controls over information which, if released, would be inimicable to the nation's security.

The 1954 act clearly expresses the will of Congress that secrecy restrictions be maintained or imposed only in the interests of the national defense. The law leaves no question as to the intention to release all possible information on technology.

One of the most outspoken critics of AEC's secrecy program, Sen. Clinton P. Anderson (D-NM), Chairman of the Joint Committee on Atomic Energy, has characterized the classification program as "capricious." He has carried on a vigorous and unending fight to force AEC to loosen up on its restrictions.

The schools of thought—there are several, of course—are in conflict. One holds that the U. S. cannot afford to take a chance on losing its lead in the world atomic progress race by publishing all technology, exclusive of pure military data. This line of reasoning is based on the belief that other nations flying now at our heels, technologically, will fill in the gaps in their programs with our information, and bound ahead, leaving us a poor second.

This argument is certainly convincing. But there's a large flaw in it: the whole idea has no legal basis. It's in effect asking that we maintain a form of trade secrecy, a factor which had no consideration in the writing of the law. It's asking that we protect the position of American firms abroad, and this has no place in a secrecy program.

A second school of thought, closely allied with Anderson's and that of former JCAE Chairman Sterling Cole (R-NY), holds that we now need more than ever a good security system on weapons information—but that we give away freely all other data.

Only through such a free-sharing system, adherents of this philosophy feel, can the United States maintain its position of world leadership in atomic energy, utilizing to the fullest its vast resources of industrial financing, technology, and brains.

The controlled thermonuclear power story is a case in point—not unless we make the facts known to all capable of contributing to its development can they have a basis on which to act. In short, if we continue to follow the unnatural limited information exchange program—easy for bureaucratic-minded officials—instead of daring to walk the tightrope of an open-ended military-only classification system, we will strangle progress in this country on the fusion process, among others.

Foreign News

West Germany Moves Ahead

The Bonn Government has dropped its initial reluctance and is now going after a bilateral agreement with the U. S. for sharing nuclear information and equipment. Officials also express keen interest in an European atomic energy pool, possibly under the Schuman Plan. Other West German developments include:

Reactors. Two reactor installations are in the planning stage, one at Munich and one at Karlsruhe. Reactors for both will come from the U. S. if government approval on both sides is forthcoming. Plans call for a swimming-pool, 10-kw reactor at Munich under the direction of Prof. Werner Heisenberg, who now heads the Max Planck Institute at Goettingen. The Karlsruhe reactor will probably be larger than the one at Munich and will use natural uranium with a heavy-water moderator.

Fuel. Germany looks to the U. S. to supply enriched uranium for the Munich reactor, but hopes eventually to mine its own natural uranium for the Karlsruhe reactor from domestic deposits. The Black Forest and Fichtel mountain regions are thought to contain uranium deposits sufficient for German needs, but official confirmation is not available.

Heavy water. Farbwerke Hoechst, an IG Farben successor company, recently announced plans to go into heavy-water production. Hoechst expects to produce six tons of heavy water annually, with production to commence within 18 months.

Nucleonics Industry. Because of Army-of-occupation bans, German industry lags behind other industrial countries in production of nuclear equipment. German industrialists were a part of the official delegation to the Geneva conference, where they appeared to pick up a new zest for the nuclear trade.

Italy Ready to Buy

Negotiations are to begin in Washington this month for export of a CP-5 type reactor for use by Italy's National Committee for Nucleonic Research. In addition, the Montecatini Co. is preparing to purchase a U. S. reactor, and the Fiat Co. is discussing a contract with Westinghouse for another reactor, although government approval is still pending. Here is rundown on the three:

- NCNR reactor will use enriched uranium, moderated by heavy water. It is to be located at Turbigo near Milan, and is scheduled for operation during 1957. Rating will be 5,000 kw of power.
- Montecatini Co. plans to use its reactor for isotope production and research. Type and location not yet specified.
- Fiat reactor, according to Italian sources, is to have rating of 10 Mw, to be located in large motor hall of Fiat in Turin, and is scheduled for operation during 1957.

By 1958 NCNR hopes to begin construction of an all-Italian reactor using domestic uranium—importing only heavy water. Although reactor will generate some power, it will be mainly for research.

Scandanavia Works, Worries

Competition from Sweden. Asea Electric Corp. of Sweden now has pilot project underway for cheap heavy-water production. Theoretical calculations place the possible price slightly less than the recently announced U. S. price tag of $28 per pound. Pilot project is being undertaken in cooperation with the Royal Institute of Technology in Stockholm. If pilot operations bear out the calculations, Asea will go into commercial production. Asea scientists believe the method employed is the same as being used by the U. S.

Asea in Sweden. The Asea Corp. is also eyeing two other prospects along nuclear lines. It wants to build a power reactor, and may eventually consider export of nuclear equipment.

Norwegian reactors. With approval last month of plans for a 10-Mw (heat) boiling heavy-water power reactor to be built by the Joint Dutch-Norwegian Nuclear Energy Establishment, work on the site was scheduled to start this month. No electricity will be produced. Process steam will be sold to a paper mill at Halden, Norway, for about 1–2 mills/kwh, the going rate for hydro power the company now buys. Excluding the cost of uranium (which will probably be slightly enriched and obtained from England) and the heavy water, the cost of the facility is estimated to be $750,000. . . . Using the "paper" experience that has been gained thus far on boiling heavy-water systems, the Norwegians have just started on a very modest study (three-man project) of applying such a reactor to merchant ship propulsion. It would be designed for 80–100 Mw (heat) . . . It is expected that the power output of the research reactor at Kjeller will be boosted from 350 kw to 700–800 kw by improvements in the cooling system.

Norway heavy water. Norsk-Hydro, Norwegian firm and until recent years sole important producer of heavy water in the world, is all in a dither about what to do about new U. S. heavy-water price of $28/lb (See NU, Sept. '55, p. 14). This is about ½ the Norsk-Hydro price. The company has contracts over the next five years with Sweden, France, Italy, India, Yugoslavia, and Holland and must decide whether it will take a loss and match the U. S. price. It is said this decision (being discussed in Oslo at this writing) will be influenced by whether or not the firm wants to go into competition on a long-term basis for the D_2O market.

Norsk-Hydro started producing D_2O in 1934 for scientific work at a rate of 1–2 tons per year. Just before the war this grew to 3–4 tons/year. Then their plant was destroyed in the war but was back in operation in '46 at a 4 ton/yr capacity. With growth in interest in reactors, the firm was pressed for heavy water by a number of countries but was said not to be too interested in such business. However, about a year ago Norsk-Hydro added new capacity to boost its output to 25 tons/year. This new plant was scheduled to be amortized with money from "future delivery" contracts mentioned above.

ROUNDUP

News in Brief

National Science Foundation makes 161 grants. Totaling $1,820,540, the grants awarded during the quarter ending June 30, 1955, were for support of basic research, conferences and studies on science, scientific information exchange, and scientific manpower register.

Firms invited to locate research in Oak Ridge. Oak Ridge Scientific Developments, Inc., organized to promote local industry, offered space to about 70 industrial concerns in a laboratory to be constructed there. Suggested advantages are proximity to nuclear facilities and personnel.

Chicago ASME exposition includes atomic section. The American Society of Mechanical Engineering exposition is Nov. 14–18 at the Chicago Coliseum, in conjunction with the society's annual meeting.

AEC issues regulation on advisory boards. Based on recommendations of the Attorney General, the regulation stipulates that boards appointed by the Commission can only furnish advice, recommendations, and opinions within assigned areas. They cannot establish policy or take action on behalf of the Commission. Membership on industry advisory committees or conferences must, when practicable, represent a cross section of those affected.

Sweden receives library of U. S. nuclear data. The library, delivered to Sweden's Atomic Energy Corp., includes practically everything made public on U. S. atomic energy experience. Similar libraries are being donated to about 30 countries. All Swedish published work is at the disposal of U. S.

U. S. plans display for Indian Industries Fair. The display pavilion for the fair opening Oct. 29 at New Delhi will have sections covering atomics, electronics, and technology. Several working models in the atomic section include a full-size graphite reactor similar to that at ORNL.

Nuclear metallurgy topic at American Institute of Mining and Metallurgical Engineers Meeting. October 17–19 meeting at the Adelphia Hotel, Philadelphia, of Institute of Metals Div. includes talks by Alvin M. Weinberg (ORNL) on reactor development, by John P. Howe (North American Aviation) on materials problems, and by Eric R. Jette (Los Alamos), H. A. Wilhelm (Iowa State), and Frank G. Foote (ANL) on metallurgy of Pu, Th, and U. This meeting is part of the National Metal Congress.

NICB Conference on Atomic Energy in Industry Oct. 26–28. The 4th annual conference on industrial applications will be held in the Waldorf-Astoria Hotel, New York. For agenda and reservations, contact: Director, Conference Div., National Industrial Conference Board, 460 Park Ave., New York 22.

U. of Chicago offers MS in radiological or health physics. Students for both degrees, awarded by the Dept. of Radiology, will be accepted in the fall quarter, 1955. Prerequisite is equivalent of BS in physics. Two-year residence is required.

AEC awards 228 research contracts. The unclassified contracts awarded to universities and private research institutions by the U. S. Atomic Energy Commission include 53 physical (8 new ones) and 175 life science (33 new).

Germantown, Md., headquarters site selected by AEC. The site, at least 50 acres and 23 miles from Washington, is considered reasonably safe in the event of hydrogen-bomb attack. The $10-million project should be completed in the fall of 1957.

Sixty-six access permits issued by AEC in August. This brings the total to 296 since the program began in April.

Atoms for Peace Awards established by Ford. As a memorial to Henry and Edsel Ford, the Ford Motor Co. Fund has contributed $1-million ($100,000 annually for 10 years) to provide for an annual award of $75,000 to the individual or group who in the opinion of a jury has contributed the most to peaceful uses of atomic energy. In the event of no suitable candidate, the money will be used for scholarships and fellowships. A nonprofit corporation, Atoms for Peace Awards, will administer the fund.

Temporary positions available at ANL. Appointments in Argonne National Laboratory are available for members of university and college faculties endorsed by their institutions. The 1-year or summer appointments may be in biology, chemistry, engineering, medicine, metallurgy, and physics. Applications should be submitted by Dec. 15, 1955.

ORINS arranges state work conferences. Oak Ridge Institute of Nuclear Studies and state academies of science have arranged conferences considering science fairs as educational tools. Conferees are from education, industry, and communications. Several scheduled are: University of Texas, Austin, Oct. 6–8; Jackson's Mill, Weston, W. V., Oct. 30–Nov. 1; North Carolina State Agricultural and Technical College, Greensboro, Nov. 18–19.

Foreign trainees to enter Harwell. Sir Christopher Hinton announced that the Reactor School at the Atomic Energy Research Establishment will be opened up for training foreign scientists and engineers.

Atomic Industrial Forum to sponsor zirconium conference. Planned for mid-November, the round-table-type conference will emphasize fabrication, reactor use, and review of metallurgy.

ORINS announces 4-week radioisotope courses. These courses instruct in the basic techniques of using radioisotopes in general research work. They are scheduled to begin Oct. 17, Jan. 9, Feb. 6, April 16, June 4, July 16, and Aug. 13. Contact Dr. Ralph T. Overman, Special Training Div., Oak Ridge Institute of Nuclear Studies, Box 117, Oak Ridge, Tenn.

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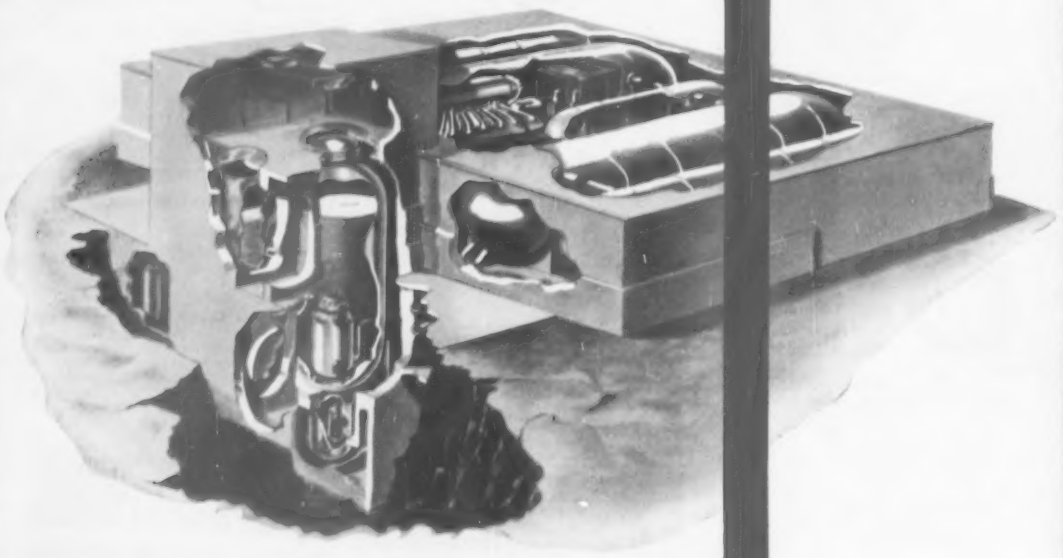

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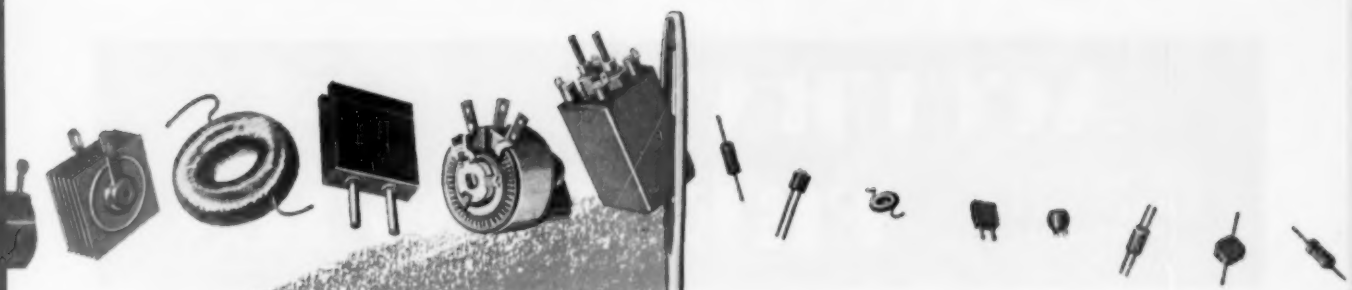

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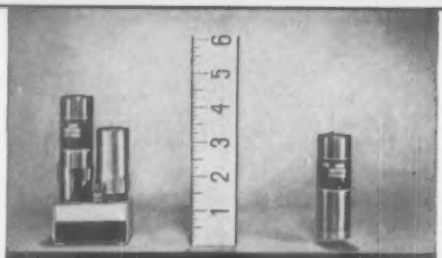
Type R 50 C
± .002% at 15° to 35°C



PRECISION FORK UNIT
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Type 50
± .02% at — 65° to 85°C

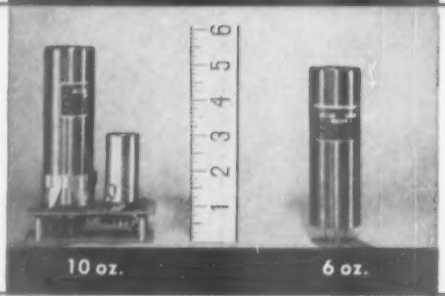
Type R 50
± .002% at 15° to 35°C

FREQUENCY STANDARD
200 to 4000 Cycles

Type 2003 C
± .02% at — 65° to 85°C

Type R 2003 C
± .002% at 15° to 35°C

Type W 2003 C
± .005% at — 65° to 85°C



PRECISION FORK UNIT
200 to 4000 Cycles

Type 2003
± .02% at — 65° to 85°C

Type R 2003
± .002% at 15° to 35°C

Type W 2003
± .005% at — 65° to 85°C

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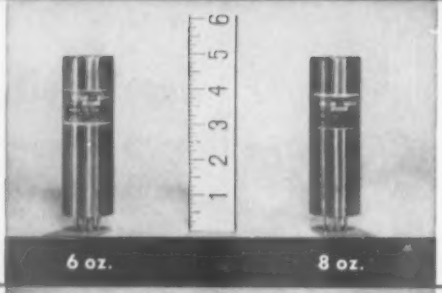

FREQUENCY STANDARD
240 to 1000 Cycles
Transistorized

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± .02% at — 65° to 85°C

Type R 2007 T
± .002% at 15° to 35°C

Type W 2007 T
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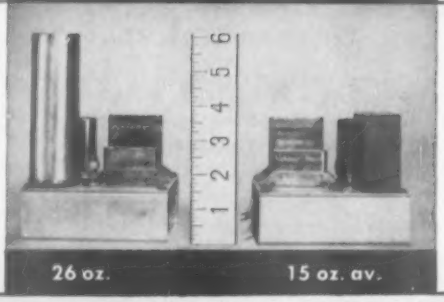

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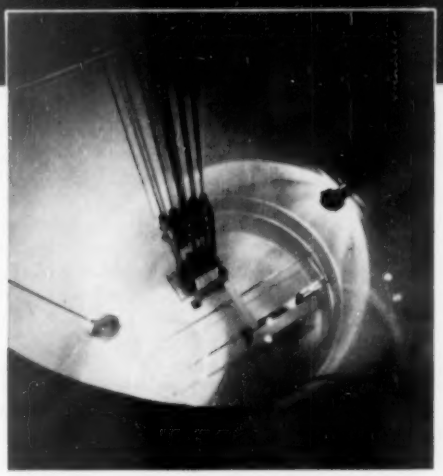

Here's what the onlooker sees when he gazes down into the Reactor's 20-ft deep "swimming pool." (Both photos courtesy U. S. A.E.C. and Union Carbide And Carbon Corp.)

Prominent among United States exhibits at the recent "Atoms for Peace" Conference, in Geneva, Switzerland, was the Research Reactor shown above. Like other research and proto-type power-producing reactors in this country and abroad, this Reactor incorporates Leeds & Northrup nuclear instrumentation. The five Speedomax recorders, in the main control panel, chart all control functions, while the L&N Servo Amplifier and Micro-micro-ammeter automatically control the Reactor when it operates at full power level.

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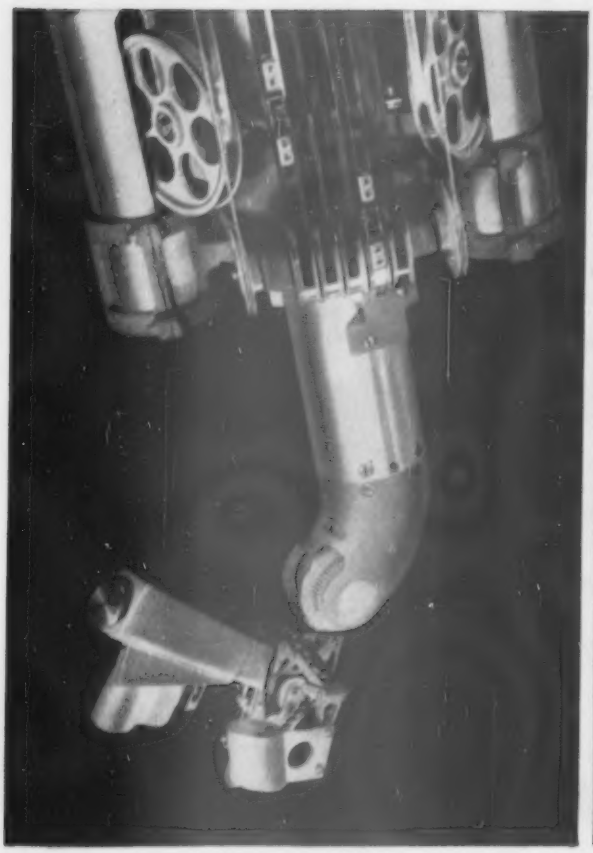

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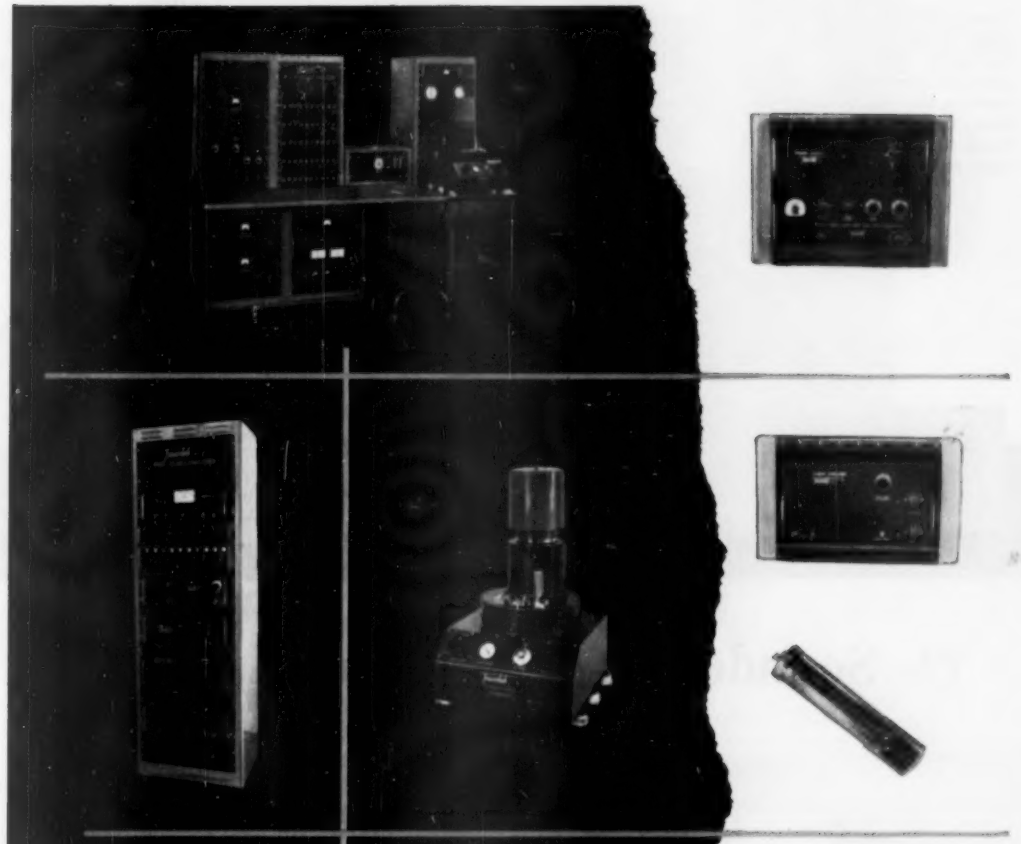

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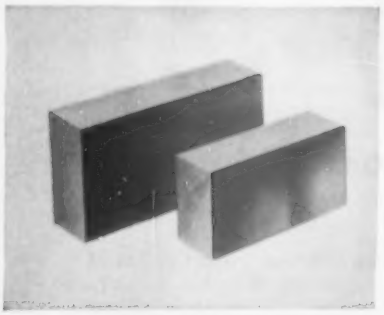
Two lead brick size 2" x 4" x 8" – one cast in an open mold (right), the other extruded through a die in a hydraulic press (left)—were sawed in half lengthwise, to show internal structure. After planing and buffing, the halves were photographed. The photos were retouched to kill highlights and achieve uniform tone on both brick. The sink and shrink-hole were not touched.

The **Sounder** *the Brick the* **Safer** *the Shield*



Conventional flat-sided National Lead *extruded* lead brick.

Curved National Lead "Protecto" *extruded* lead brick.

Extruded lead brick are bound to be sound. The extrusion process – forcing metallic lead through dies – insures an internal structure that is solid, and an external surface that is smooth and uniform. There are no hidden voids and shrink-holes to lessen the protection of the shield, no rough surfaces or "sinks" to be machined flat before the brick can be stacked straight and true.

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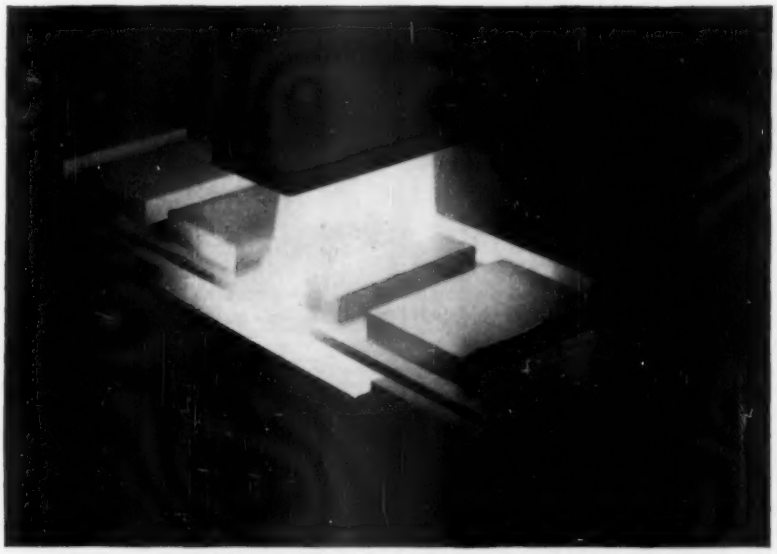

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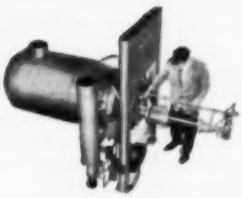

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We are proud that McGraw-Hill publications were among the founders and charter members of the Audit Bureau of Circulations.

Today the Bureau numbers 3,670 members. These include advertisers, agencies, and publishers of newspapers, farm papers, general magazines and business journals such as this one. These publisher members hold their memberships and their right to display the ABC symbol in their publications only so long as they live up to the circulation standards that are established through the Bureau.

It is one thing to set up high standards; it is another to see that those standards are maintained. This latter and all-important function is performed by a staff of auditors maintained by ABC to check periodically on the circulation practices of the publisher members. When a business magazine, such as this one, joins the Bureau it agrees that the ABC auditors shall have "the right of access to all books and records." Their inspection may dig into the files of original subscription orders, payments from subscribers, paper purchases, postal receipts, arrears of payments, editorial expenses and many other significant items. Sometimes the auditors go behind the records and seek verification of purchase and payment from subscribers themselves.

The information thus obtained and certified by the Bureau then becomes available to the public and constitutes an authoritative report on the publication's circulation practices.

The advertisers and agencies benefit directly from the ABC because it provides a generally recognized factual yardstick by which the circulations of member publications can be measured and appraised. Every paragraph in an ABC report on a business publication gives the advertisers data that help them make intelligent use of the publication as an advertising medium.

But the ABC renders a service of vital concern to the *reader* as well. The Bureau audits paid circulation only, and it is through this payment, whether by subscription or newsstand purchase, that the reader keeps the editorial policy of a publication responsive to his needs. His decision to buy or not to buy records his judgment on each publication, and the ABC-audited and certified circulation reports make the sum of these judgments known to all concerned.

So the editors of ABC publications must constantly keep their editorial services up to the mark if they are to survive a competition in which the reader's right to buy or not to buy is paramount. Each paid magazine or newspaper will prosper or fail as it wins or loses the voluntary patronage of thousands or millions of readers. And—the ABC is scorekeeper in this vital contest.

Thus the publisher who submits his publication to the supervision and discipline of ABC affirms in the strongest possible manner his recognition that his primary obligation is to his readers and that he owes the standing of his publication to a voluntary demand by those readers.

All this is what makes the ABC brand on a publication so important to its readers. That respected symbol, testifying to the advertising value of the publication, serves also as a constant reminder to all concerned that the reader's willingness to pay for an ABC publication is the basic reason why it stays in business.

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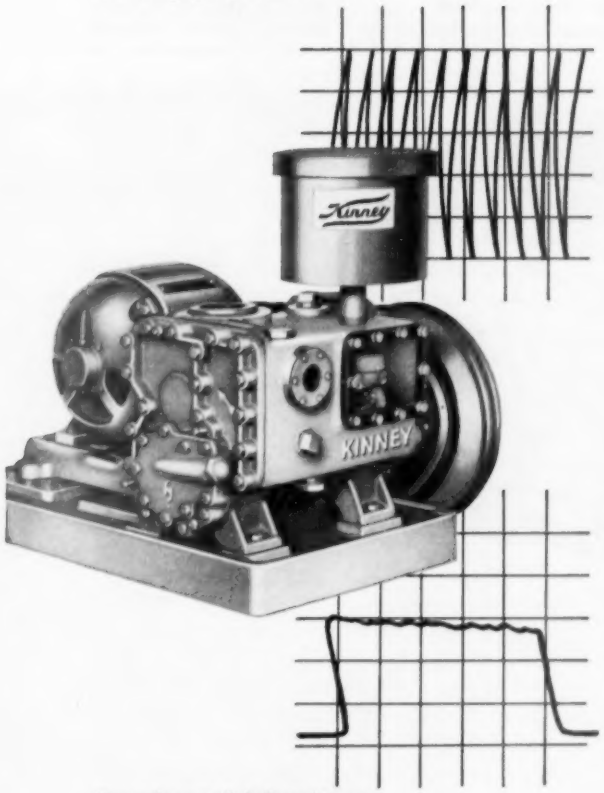
Here's the kind of curve an ordinary vacuum pump plots on a vibrograph. This might be called "nerve-shattering" performance.



Kinney dynamically balanced Pumps plot a curve like this. If you need vacuum, balanced performance is another reason why you need Kinney.

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PRICE is $249.60* and the detector is available from stock. For further information contact nearest G-E Apparatus Sales Office, or write for Bulletin GEA-6117, Section 605-81, General Electric, Schenectady 5, N.Y.

*Manufacturer's suggested retail price

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NUCLEONICS OCTOBER, 1955

Jerome D. Luntz, *Editor*

Geneva in Retrospect—Some Personal Reactions

LONDON—I am writing this three weeks after the Geneva conference, having visited the atomic energy establishments in France, Belgium, Holland, Sweden, and Norway and just prior to visiting in England. This provides a good perspective for examining the effects of recent developments on countries with and without the vital nuclear materials—uranium and D_2O.

First, it is clear that Geneva has given the whole nuclear business a tremendous shot in the arm. As emphasized to me by someone in Belgium, it's going to be a lot easier to get management support for nuclear projects—because people are nuclear conscious now.

Wherever I went—and in countries referred to in the article on bilateral agreements, p. 30—I found that an important part of the motivation to have an atomic energy program was the feeling that one "should" have a program. In many places where there is no immediate urgency to have a new power source there was the strong desire to train people to gain experience in anticipation of the development of self-sufficient programs. It is now quite evident that the next three years or so will see considerable activity on building and planning of reactors. Some countries want to build equipment themselves. Others are customers for ready-made facilities.

OPPORTUNITIES for U. S. industry to sell abroad are great. By reason of experience, diversity of background, and the backing of far and away the largest governmental program in the world, U. S. firms have the edge over their nearest competitors in the U. K. However, they have got to do a hard selling job to maintain the advantage. More important, the Atomic Energy Commission has got to quit procrastinating, recognize the importance to the U. S. of a strong nuclear export business and announce a policy of positive encouragement of industry in dealings with foreign countries (including mechanisms of negotiations, availability of fuel for reactors sold, etc.). At the moment and in the next several years no other country has firms in a position to offer competition in reactors, except perhaps for components.

Of overriding importance in world-wide atomic energy activities is the question of availability of nuclear fuel—particularly enriched uranium or plutonium. More than anything else, this is affecting the course of nuclear programs. This was emphatically borne out when at least several countries changed their reactor plans overnight when they were offered U. S. U^{235}.

Decisions must be made by many nations on whether they want to be dependent on uncertain availability of U^{235}, whether they prefer to produce Pu and thus need to build chemical separation plants, or what. Some consideration is being given in Europe to the erection of common gaseous diffusion plants and plutonium separation plants, but it doesn't appear likely that this will happen. It is inevitable, however, that Pu recovery facilities will be built by a number of nations.

Not to be overlooked as a vital material is heavy water. Only the U. S. and Norway now sell it. England and France will soon have their own supplies. However, the U. S. with its very low price of $28/lb can corner the market if it wants to. In any event, it is obvious that, as with U, heavy water will be used as an important item in international atomic bartering.

WHAT all of this points to is the need for a strong international agency to coordinate the distribution of strategic nuclear materials, particularly fissionable fuels. When a country builds a nuclear power plant, it must be assured of a continuing supply of fuel. The agency, buying the materials from different "have" nations, might do this best.

It might even take the ultimate step and build its own U^{235} and Pu separation plants.

Perhaps a more important reason to have the agency control fissionable materials is one of safety. There is going to be an increasing need for a body such as this to police against misuse of U and Pu. In addition, another major function would be for the agency to have jurisdiction over such matters as reactor safeguards, waste disposal and radiation protection in so far as activities in one country affect people of another.

With the tremendously growing tempo of nuclear activities around the world, international cooperation to further individual programs and at the same time to protect the peoples of the world is vital.

How Foreign Countries Are Using U. S. Bilateral Agreements

An important part of the U. S. "atoms for peace" program are the bilateral agreements for cooperation in atomic energy. The U. S. has negotiated 26 such agreements. Three of these—with Belgium, Canada, and the United Kingdom—are special and cover exchange of classified information. Because of lack of general public awareness of nuclear activities in the other 23 countries, NUCLEONICS interviewed their principal delegates to the United Nations nuclear conference in Geneva

ARGENTINA

D. PEDRO E. TRAOLAGOITIA

Chairman of the Comision de Energia Atomica

For our country, the main advantages of the bilateral agreement are: (a) we shall obtain a small quantity of enriched uranium for our research needs, and (b) we shall be able to go faster in our research work.

Atomic organization. In 1950 we set up a "Comision Nacional de Energia Atomica—Atomic Energy National Commission—of which I am the chairman. So far, the Commission's financial needs are met only by the State; 175-million pesos were spent from its inception to November 1954—the equivalent of one day's expenses of the U. S. AEC. We have already built a 30-Mev synchrocyclotron and are reporting here on research with it.

A new law now is being submitted to the Parliament, which determines the statute of the Commission and will also permit contributions from other sources than the State to be received. The latter is exceptional legislation.

Reactor and power plans. We do not plan to buy a research reactor for the time being. Our plans call for the building of a power-reactor prototype, importing only some parts, such as turbogenerators, from Europe or the U. S. We believe we shall start building this prototype more or less than a year from now; construction will need three or four years.

This will be a reactor for natural uranium in metallic form, as we want to be able to rely on our own natural uranium resources. We are actively prospecting for uranium and thorium, and we are already exploiting and purifying the former. In fact, just before leaving to come to this Conference, I saw the first Argentina-made bar of metallic uranium.

During the past three months, very promising deposits of both metals have been discovered in the north of our country. By the time our pilot power reactor is ready, we expect to have mined enough uranium to meet the needs of the first ten years or so of functioning. After this period, uranium is bound to be more freely available than now, and we expect no difficulty on this score. By then we shall have surmounted our present difficulties in purification and metallurgical processing.

We plan to set up nuclear power plants only in the parts of our country where the installation of transmission lines is difficult or very costly, developing our hydroelectric resources everywhere else. By 1980 we expect to cover about 50% of the needs at that time, some 3,000 Mw, by using nuclear power.

Manpower resources. Our main manpower problem is lack of teachers; we have to use Atomic Commission members as professors in many instances. This is not a satisfactory situation.

Students in this field are enthusiastic. At present we have about 10 graduates doing special studies abroad: four in the U. S., two in the U. K., two at Göttingen, Germany, etc. By the end of 1955, we shall have 20 specialists being trained abroad.

We have just opened, on August 1, a new Physics Institute under the patronage of the Commission. This is at the University of Cujo, Bariloche (Rio Negro), where the students will live and study nucleonics intensively. Now 15 students are there, but the number is bound to increase rapidly.

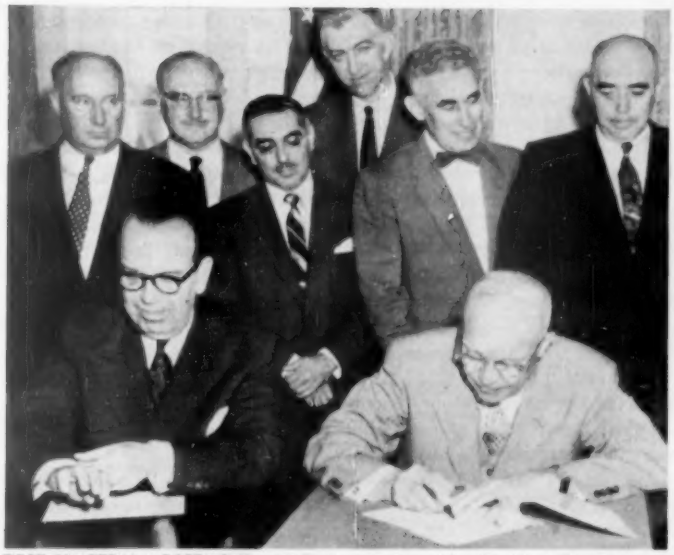
BRAZIL

BERNARDINO DE MATTOS

Chairman, Atomic Energy Commission of the Brazilian National Research Council

One of the consequences of the bilateral agreement is that Brazil will be able in a short time to get the enriched uranium necessary for construction of its first research reactor. This reactor will constitute an important step towards development of the Brazilian Atomic Energy Commission reactor construction program.

Atomic organization. The Brazilian Atomic Energy Commission was established at the beginning of this year in the framework of the Conselho Nacional de Pesquisas, for which the federal budget had already been approved by Congress. Hence the Atomic Energy Commission has not yet its own specific budget; nevertheless all the funds necessary for the development of its program are being supplied by the Council. The Atomic Energy Commission is developing some laboratories for nuclear research and is sponsoring research in some of our universities for specific programs in atomic energy and related matters. Besides, the formation of a group of trained personnel is being fostered by the establishment of



FIRST BILATERAL AGREEMENT, with Turkey, is signed by President Eisenhower in the presence of Turkey Ambassador Feridun Erkin, May 3, 1955

research grants for training in Brazil and in foreign countries.

Brazil already has a tradition in nuclear researches and has modern accelerators in operation for investigation in the binding-energy region. Although a great part of the research equipment is manufactured in our country, foreign equipment is continuously bought abroad according to the needs of our program.

Reactor and power plans. The extremely rapid rate of rise of our industrial development, notwithstanding our large resources in hydroelectric power, makes it necessary to use other sources of power to supply growing needs. Since Brazil is very rich in atomic fuels, there is no question that atomic energy will play an important role in the near future.

Manpower resources. Brazil's situation regarding trained personnel and manpower in 1952 has already been published (NU, Dec. '52, p. 31). Since then, the situation has improved a great deal due to the attention being paid by the Conselho Nacional de Pesquisas and by our universities to this problem.

CHILE

CARLOS RUIZ
Subsecretary, Mining Ministry

This recent agreement is going to be very useful to us, as we intend to develop studies of nucleonics as rapidly as possible. We must first train technicians and then get a research reactor. We hope the U. S. will help us on both.

Atomic organization. We have a National Commission for Atomic Energy (Comisión Nacional de la Energía Atómica), presided over by the President of the National University of Chile. So far, it is a study and discussion committee, with no laboratories of its own. It uses the services of the Economic Development Corporation of Chile for material facilities.

This same Corporation, which is a Government agency and receives U. S. technical help, has been prospecting for uranium deposits in our country since 1952. We are confident that we will find sufficient uranium for our own needs inside our national boundaries.

Reactor and power plans. We plan to buy a research reactor very soon, if at all possible next year. We have not decided where we will buy it, but it will be either in England or in the U. S. —more probably the latter.

As a next step, we want a power reactor, capable of working with metallic natural uranium, so as to use our future production directly. We believe we shall be among the first countries in Latin America to use a power reactor. While we have sufficient hydro-electric power sources in the south and center of the country, the northern part, which is where most copper and other mines are located, is very dry, and badly needs electric power. Coal being too expensive, it seems that atomic power might be the solution for us. We have a yearly fuel consumption of one million metric tons, $20-million.

Concurrently, we will have to develop our concentration plants and techniques, and here we expect the U. S. government and private companies to help us in many ways.

We would also welcome atomic plants established in our country by U. S. or other foreign corporations. Nothing in our legislation prevents such construction; there is no exclusion law.

Manpower resources. This is one of the main obstacles to our rapid development, together with finances.

The University of Chile, at Santiago, is setting up a program for the training of nuclear physicists and establishment of scholarships. We shall also send capable students abroad for post-graduate studies. Here we are only at the beginning—the University has no special nucleonics course yet, but this will come soon.

COLOMBIA

ALVARO LUQUE
Cancer Institute of Bogota

A lot depends on the help we can get from the U. S. both in prospecting and for training our people.

Atomic organization. There is no central authority for nuclear energy in Colombia yet, but I believe the government intends to set up one.

Reactor and power plans. We have made no decision yet on reactors. I believe the government intends to buy a research reactor from the U. S., for investigations and the preparation of isotopes. But only after we have prepared the people for its use.

Manpower resources. Before getting a reactor, we need at least 18 or 20 nuclear physicists. It will take a couple of years to train them. Also, our universities aren't yet sufficiently well equipped. The only places with some good instruments so far are two government agencies, the Superior Institute of Geology and the National Chemical Laboratory, both at Bogota.

Some of our specialists will have to be trained outside the country. I know that Dr. Zuleta Angel, ambassador to Washington and head of this delegation, soon will discuss the matter in Washington and that he will also

suggest the setting up of a special Institute for Nuclear Energy Studies.

DENMARK

A member of the Danish Delegation

Thanks to the agreement, we shall be able to acquire a research reactor soon. We are at present here discussing details with our friends of the U. S.

We also have an agreement with the British.

Atomic organization. This year, we have set up in Denmark a National Atomic Energy Committee, of which Professor Niels Bohr is Chairman. The Committee is made up of 15 members, has a working group of 5 members—physicists, engineers, and one member from the Administration. Funds for its program are received from government sources.

Reactor and power plans. We plan the setting up of two research reactors. We don't know of which type yet. Our discussions here are helping us frame the answer.

As to power reactors, it is much too early to tell if and when we shall have them. Whether we build ourselves or import them ready-made will depend on the conditions of time, etc.

Manpower resources. Trained manpower is not a big problem. We have a number of generally trained nuclear physicists. We welcome the opportunity for special training offered us by the U. S. and Great Britain.

Our center of learning in nuclear physics is at the University of Copenhagen under Professor Bohr. The University is quite well equipped.

GREECE

TH. G. KOUYOUMTZELIS

Professor of Physics, University of Athens; Secretary General, National Atomic Energy Commission

Only thanks to the U. S. agreement can we contemplate purchasing a research reactor in the near future. And it will also permit us to send more people for study to the U. S.—so far, on account of expenses, it was Europe.

Atomic organization. Last year, Greece set up a National Atomic Energy Commission, of which I am the Secretary-General. The Chairman is Admiral Spanidis. The 25 members of the Commission serve as advisers to the government in all matters pertaining to the atom. Twelve are professors, five belong to the military, and eight represent various interested government departments.

This Commission will soon become the center for all atomic studies in Greece, when it gets the equipment it needs. It is exclusively government-supported and soon will spend $20,000–40,000 in purchase of equipment, mainly from the U. S. In October, I shall go to the U. S. and order some of this equipment.

To spread the use of isotopes is one of the most urgent tasks of the Commission. By law, importation of isotopes is subject to a Commission permit.

The Commission plans are: (a) to develop fellowship programs with the help of funds provided by FOA and the United Nations Technical Assistance program; (b) to set up this winter a good laboratory for nuclear studies and research (so far our teaching has been mostly of the blackboard type); (c) in a couple of years or so, to install a research reactor in Athens.

Reactor and power plans. We have not decided what type our research reactor will be. Most probably we shall buy from the most favorable source, the U. S., thanks to the agreement. We need the reactor not only for research but also for production of short-lived isotopes—importing them from Harwell turned out to be too impractical.

The Commission does not intend to set up, even later, power reactors. It will be restricted to scientific work and will only advise the government on this.

Industry will have to set up the power reactors. According to our calculations, we shall be very short of electric power in ten years from now. By then we shall know more about the cost of atom-produced electricity. But I presume it will be a new fuel that we can use advantageously. The Conference did not give us exact figures on power costs, so we have to wait.

Manpower resources. We lack of nuclear physicists today. So far, nucleonics is taught only briefly by general physicists. But we have two people working at Argonne on nuclear research; we have one or two at Copenhagen, with Prof. Bohr, and at CERN in Geneva. The agreement will permit us to send many more to the U. S. from now on. But we also contemplate sending people on shorter study trips (one month or so) to Harwell, for instance. Prof. Alexopoulos, also Professor of Physics at the University of Athens, and myself, will, for instance, spend 15 days in Norway and visit the Kjeller reactor after this Conference. Also, Prof. Pantazis, of the University Department of Zoology, will visit France and the U. K.

ISRAEL

WALTER EYTAN

Director General, Ministry for Foreign Affairs

We signed the U. S. agreement as a starting point; we are bound to take an exceptional interest in creating our own energy sources. Our electricity needs double every four years. We are poor in domestic fuels—no oil, no coal—and we depend on oil imports for our power supply. On account of the boycott by the Arab countries, we cannot get oil from the nearest sources, Iraq and Saudi Arabia, but must import it all the way from Venezuela.

Atomic organization. We have been interested in atomic research since the very inception of our State (1948) and started work immediately. In 1952, our central agency (Atomic Energy Commission of Israel) was set up by the government. It has its own budget and laboratories. Prof. David Bergmann is the Chairman of this Commission, and Dr. Israel Dostrowsky its Director of Research.

Apart from the Commission's laboratories, where the top-scientists work, atomic work is concentrated in three institutions: the Hebrew University in Jerusalem, the most important where most students work; the Weizman Institute of Science at Rehovot, where several graduate scientists work exclusively in nuclear research; and the Technion in Haifa, mainly engineering and metallurgical studies.

Reactor and power plans. To eliminate power dependency, we have done research and have already achieved promising results in two fields: nuclear and solar energy.

In 1948 we discovered large phosphate deposits in the Negeb containing uranium of 0.1 to 0.01% content. We have studied and found a sufficiently economic process to extract the metal from the phosphate ore, which

Reactions to the United Nations Conference

One highlight was appraisal of scientific and technical contributions from different countries. Another was establishment among scientists of a more ample cooperation.

—De Mattos, Brazil

The greatest impression this conference made on us is one of deep surprise at the considerable advances made in this field during the past few years. Especially we realized for the first time that we have already reached the "commercial" stage in the production of reactors.

—Ruiz, Chile

The period of secrecy is now over, forever probably. We can at long last work normally in developing this new science.

—Giordani, Italy

Only here did we realize how far ahead the advanced countries have gone. We also learned how expensive reactors are . . . Now that the United Nations has put a hand in this, we hope it will not stop at that. Giving knowledge is fine, but assistance to underdeveloped countries in using this knowledge for their own good is even more important. We hope UN Technical Assistance, in particular, and other agencies will help us in this field as they do in others.

—Ahmad, Pakistan

At first, I thought that propaganda was the main aim, but I soon realized that the scientific aspects did take the overhand. The nations now realize they must conduct exchange of information if they want to go ahead. Also, the friendly contacts between East and West mean a lot to us.

—Serrano, the Philippines

We particularly appreciated the American presentations. We have also been quite surprised at the willingness of the Russians, for the first time, to answer our questions and to exchange information. They have even approached us on their own initiative. We have also strengthened our contacts with the U. K. From the point of view of our public opinion, the conference is tremendously important. It has blown away the atom bomb scare and shown that the atom is above all, or can be, an instrument of peace and better living.

—Scherrer, Switzerland

We now know whom we shall contact on future problems.

—Rangsrisht, Thailand

This is a real school for us; we have gathered extremely useful information that we shall have to study and digest for years—and translate in part into Turkish for our students, as all teaching is done in Turkish in our universities. We found the atmosphere much more friendly than we had expected and made very useful contacts.

—Tanyel, Turkey

We have learned more in these few days than in months of study. But in a way we did not get a categoric answer to our two main problems: which power reactors are most convenient for our country, and, even more important, what the cost of medium-sized reactors would be. Reactors still seem too expensive, but we shall continue the study of these questions with fresh impetus.

—Hill, Uruguay

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also can be applied to other similar low-grade ores. We consider that even with the 0.01% phosphate the process is economical, for we use the remainder.

We have also developed our own process for manufacturing heavy water by a distillation process; we are perfecting it now. We are too poor in electricity to use other processes.

As to solar energy, this might be our greatest future fuel source. We are very rich in sunshine, and will do all we can to utilize it. Here too, we are making good headway. It may even be that we shall produce electricity by solar power sooner than we produce it by nuclear power, and cheaper. Our specialist in this field, Dr. Henry Tabor, of the Scientific Research Council of Israel in Jerusalem, is pushing experimentation as fast as possible.

Manpower resources. We need to train more men, but we shall find them easily. We are rich in high-class brains, and as far as possible we want to train our people at home. However, as we have done previously, we shall send missions from to time all over the world to improve our knowledge.

ITALY

FRANCESCO GIORDANI

Chairman, National Committee for Nuclear Research; Professor of General Chemistry, University of Naples

As a result of our agreement, we shall build a CP5-type reactor, partly built in Italy, partly imported from the U. S. Within two years we expect the reactor to be completed near Milan.

Atomic organization. We shall follow the system used by the U. S.—the government keeping the property, but using a contractor to run it. In Italy, this contractor is the CISE (Centro Informazioni Studi ed Esperienze—Information, Studies, and Experience Center), an organization which started under private auspices and is now under the new central agency (the Committee of which I am chairman). Expenses are shared fifty-fifty between government and private sources. However, cost of the reactor will be borne entirely by the government.

For the time being, the government is giving two billion lires a year for nuclear research (about $3-million).

For fundamental research, we have the Institute for Nuclear Research, which acts through four sections—in the Universities of Rome, Turin, Milan and Padova. And for engineers we have Milan Polytechnical School courses.

We also have people working in the CISE plants and laboratories. We have some good equipment, but our accelerators are too small. In Turin we have a 30-Mev betatron and a 100-Mev electron synchrotron. Near Rome we have just started building a 1,000-Mev synchrotron.

Reactor and power plans. In ten years we shall have more or less exhausted our hydroelectric potentialities, so we will need other fuel.

We wish to make another agreement with the U. S. for a power reactor. I plan to go to the U. S. in October to discuss this. The press has been already talking about negotiations between FIAT and Westinghouse (see NU, Sept. '55, p. 14), but nothing has been decided. These are only preliminary contacts on possibilities.

We have some uranium in Italy and have mined very small quantities—in

the order of tens of tons. We have, for instance, been able to remit 50 kg to Switzerland, as a symbolic gesture.

JAPAN

YOSHIO FUJIOKA
Faculty of Science, Tokyo University of Education

Atomic organization. We have no central agency for atomic energy yet, but our government is contemplating the setting up of such an institution, probably to be half governmental, half civilian. A draft statute has not been prepared yet. This will not be before 1956, as it has to wait for the next regular session of Parliament.

In 1955, a small private agency was set up and a small grant made to a committee, but this setup will have to be revised next year. It is not satisfactory, especially because nobody is really responsible. We need a supervisory organ.

Reactor and power plans. The future agency will erect a center, probably near Tokyo. To start with, we shall import from the U. S. a research reactor, so as to train our scientists.

Then, our mission that toured the world recommended to the government the building of a reactor designed by Japanese—heavy water and natural uranium type—and possibly of pilot reactors for each type. But this will depend on the budget granted to the future central organization for atomic research.

I believe we shall probably use atomic fuel in 20–25 yrs. We can still double our hydro-electric output, but plants are getting more and more expensive. We will also improve our somewhat antiquated coal-burning plants, but even so there will be a crisis in 20–25 years.

In spite of newspaper claims, it is not certain yet that we have commercially useful uranium deposits in Japan. Prospecting is going on, but no definite answer can be given at present.

Manpower resources. So far, Japanese industry has no experience in atomic energy to speak of. We have a little experience in cyclotrons, but we need many more trained nuclear physicists and must educate them.

This is why we have sent people to Argonne and Oak Ridge courses. So far, our people have only gone to the U. S. for such training. We wish to send high-level people not to school courses, but to do practical work.

KOREA

CHULCHAI PARK
Director, Bureau of Technological Education, Ministry of Education

We expect many benefits from the agreement, especially in the training of our young physicists.

Atomic organization. We have no national agency yet, but the government is studying a law to set one up.

Reactor and power plans. We shall not be able to do much until our first trained people come back from the U. S. in three years or so. Then we plan to get a research reactor and start working in Seoul itself.

As we are a country without coal or oil, atomic energy is important to us, in particular as we are prospecting the country for uranium. We have already sent some samples to the U. S., but haven't received the results of analysis yet. The future is nevertheless promising. If we have suitable uranium deposits, they will be jointly exploited by the U. S. and us.

Manpower resources. We have no chair for nuclear physics at the National University of Seoul yet, but we expect to have one in a couple of years. We expect to send six people to Oak Ridge soon. Some of our people are in the U. S. now—for instance, Dr. Lee, who is a member of the delegation, does post-graduate work at Florida State.

LEBANON

SALWA NASSAR
Professor of Physics, American University at Beirut

Lebanon signed the agreement only recently. So far, no practical steps have been taken. However, progress will be rapid, especially as Camille Chamoun, President of the Republic, is personally very interested in nuclear power. As soon as we are ready, we expect to get great help from the U. S. for the realization of our program.

Atomic organization. We have no central atomic authority yet. The five or six Lebanese scientists trained in this field got together some months ago, with the blessing of the President of the Republic, to set up a charter for such an authority. The charter draft is ready and is being studied by the government. It proposes the setting up of a National Scientific Research Council that would mainly, but not exclusively, deal with atomic energy problems. It also suggests that 1% of the national budget be dedicated to the tasks of the Council (which would mean about $500,000).

If the charter is accepted, the first thing we plan is to establish laboratories, then chose the staff and award as many scholarships as possible.

Reactor and power plans. As to the possibility of setting up a reactor of any kind, this is still remote. After a while, if funds are available, the future council may buy a research reactor of the smallest available type, but the setting up of a power reactor—at least by the government—is still very far off. A new $25-million irrigation project will produce a large quantity (for Lebanon) of electricity as a by-product. We do not think nuclear power has a chance for a long time to come, due to the small size of our country.

A rather inadequate study of possible resources of uranium ore in Lebanon was made some time ago, with negative results. A new search should be made, with modern instruments. This would be one of the tasks of the future National Scientific Research Council.

One of the most useful things we learned here is that uranium ore may be found even in sedimentary rock—hard limestone—as we have generally in our country. We always thought, up to now, that this rock was not promising at all in this field, so we will start again with fresh encouragement.

Manpower resources. This problem is a great one. Up to now, we have only a handful of trained professors, scattered in our three institutes of higher learning: the Lebanese University, which is a recent creation, the American University, and the French-inspired Center for Physics and Mathematics (Centre de Physique et de Mathématiques). We have no institution yet capable of delivering doctorates, which must be obtained abroad.

Our greatest difficulty will be to have enough teachers. We have at present only about half a dozen students specializing in this field abroad, in the U. S., U. K., continental Europe (France), and even one in New Zealand. The main difficulty is the cost of studying abroad. We are benefiting

from some U. S. scholarships, and could probably obtain more than we use. Only a minority of scholarships are granted from Lebanese funds.

We have only about four capable teachers in physics, and we shall need five or six time more. At the Lebanese University, there are about 50 students studying physics, but it is impossible yet to say how many will later specialize in nuclear power.

THE NETHERLANDS

J. M. W. MILATZ
Director, Reaktor Centrum Nederland; Professor, University of Utrecht

The agreement with the U. S. will permit us to buy a materials testing reactor rapidly. We haven't chosen the type, but are currently discussing the matter in Geneva.

We have another agreement with the U. K. through which we shall get some enriched uranium, and an agreement with Norway for the delivery of D_2O.

Indeed, with Norway it is more of a group effort than a simple agreement. We have agreed that we shall use our reactors in common; the Norwegians will build a 10-Mw steam-producing boiling-water reactor that complements our program.

Atomic organization. Our central agency for nuclear energy is the Reaktor Centrum Nederland, of which I have recently been named Director. Chairman of the Board is Dr. Hirschfeld.

This organization's support comes 50% from the Dutch government, 25% from the electrical factories of the Netherlands, and 25% from the rest of Dutch industry. Its total budget is estimated at 28-million Dutch guilders (about $7.5-million). For the first year, the budget is 1½-million guilders; this will increase year after year.

Reactor and power plans. We plan to build in Holland a 20-Mw materials testing reactor with very high flux—about 10^{14} n/cm²/sec. We shall build it with the help of American industry; it will be under construction for two or three years.

We also have decided to build a 250-kw research suspension reactor based on the design we have described at the Conference. This is to be built by KEMA, the laboratory of the Dutch electrical factories.

The site of the larger Dutch reactor has not been selected. We need a large space for it.

Our reactors will serve primarily to stimulate our industry to produce electricity—our needs double every ten years and we may soon have a shortage of coal—and for scientific and technical education of our physicists. But a field in which we are particularly interested is ship propulsion.

Manpower resources. Our physicists are being trained partly in the U. S., partly in the U. K., and partly in Norway.

PAKISTAN

NAZIR AHMAD
Chairman, Atomic Energy Commission; Chairman, Tariff Commission

Our government fully realizes the importance of atomic energy for the future. That is why we signed the bilateral agreement with the U. S. We expect many advantages from it, although we are only at the beginning.

Atomic organization. We have recently set up a national agency, called the Atomic Energy Committee, which will supervise the whole field. It is made up of 12 members, scientists, engineers and government officials, nominated by the government. I am the chairman of this agency, which will advise the government on all matters pertaining to atomic energy, research, etc. For the current year, the government made a grant of 2½-million rupees (about $600,000) to the committee, quite a sizable sum for our country.

With these funds, which will probably grow year after year, the committee will first train Pakistani in nuclear physics, then set up a research reactor.

Reactor and power plans. The first research reactor we shall need should be somewhat more powerful in flux than the one exhibited by the U. S. at Geneva. But before we can purchase it, we have to finalize our plans for the training of our atomic scientists (see section on manpower resources).

At a later stage, we shall have to build or purchase a power reactor. Plans are not advanced enough to indicate when, but in any case we shall have to get a new source of power around 1960–1965, when our present possibilities will be nearing exhaustion. Soon our total supply of conventional fuel will fall short of our total requirements—the gap is widening every day—and we shall have to use atomic fuels.

The government is at present organizing a survey of ores, in particular, uranium and thorium. It is too early to tell, but we may be able to get our raw fuel from our land in the future. There is a good probability of success.

We do not know yet if we shall use enriched fuel. We shall probably be able to make arrangements for having our own mineral enriched in the U. S. or England, or exchange it for enriched fuel, or we might by then prefer a reactor that can use natural uranium, for instance. In this respect, we shall see more light after we go to Harwell, after the conference, and have seen the British project for use of natural U.

Manpower resources. Our trained manpower is still terribly insufficient. And it is in this respect that we expect most help from the bilateral agreement. We are sending as many men as we can abroad for study—mainly to the U. S. but also some to England. Quite recently, the first group of four returned to Pakistan from the U. S. They will either teach nuclear science or go into research, probably both at the same time. But we need many more.

We have so far only about two dozen of scholarships in this field (including cosmic-ray studies, etc.) out of a total of some 400 science students abroad.

This gap may soon be closed, as there is a very great enthusiasm among our youth for physics, and in particular nuclear physics. Our universities at Karachi, Daca, Pashavar, Lahore will soon have specialized teachers in nuclear physics, so that a few years from now we will be able to think seriously of purchasing a research reactor for them. Specifications will be set up, and we shall probably buy the reactor where we can find the most advantageous terms for such purchase. Meanwhile, the agreement with the U. S. permits us to get isotopes, train young scientists, and get basic equipment favorably.

PERU

GEORGE SARMIENTO
Chairman, Radioactive Substances Control Board

The agreements with the U. S. are the key to our atomic energy and resources politics. We have two agree-

ments: one, signed September 14, 1954, by which we undertake to place all our available uranium resources at the disposal of the U. S.; the other, signed in June 1955, providing facilities for the purchase of research reactors.

Atomic organization. We have no national nuclear energy commission yet, but we are contemplating the establishment of one. Then, the Board of which I am the chairman (comparable to the Raw Material Division of the U. S. AEC) will probably become a part of this central authority.

At present, the Board concentrates on help for those who are prospecting the country for uranium, etc. We supply U. S. purchased instruments without profit or taxes; we supply free analysis; we also provide literature.

We have started systematic prospection of uranium deposits in our country and have already sent samples to the U. S. AEC for examination. There are good prospects of discovering usable deposits, as signs of radioactivity exist in many parts of the country.

Reactor and power plans. Sometime in the near future, we shall buy a research reactor in the U. S., but I cannot yet tell when.

As to power reactors, it is too early to give an opinion. We have coal, oil and hydropower in Peru, and are developing these fuels as much as possible. But a time may come when, in certain parts of the country at least, it may be more profitable to set up atomic energy plants. Then it will be up to industry, domestic or foreign, to set up such reactors. Our laws in this respect are probably the most liberal in all the Latin American countries: there are no restrictions against export of profits, and currency is freely exchangeable. Our government tries to attract foreign investments to develop the many numerous opportunities Peru offers.

Manpower resources. Trained manpower is a great problem. Some of our schools do train physicists, but we have no special teaching for nuclear physics now. We haven't yet sent graduates to the Argonne reactor school, but we shall soon. We shall also select appropriate people for further training in U. S. special courses.

There is also a plan to establish, later this year, an Institute of Superior Physics at Lima, which will be of great help in the training of specialists in nuclear science.

The Peruvian government in certain cases gives study grants to selected people (for instance against a promise to work for the government later) to study in the U. S. Even when they must pay their own studies, our students prefer to go to the U. S. than to any other country.

THE PHILIPPINES

FELIXBERTO M. SERRANO
Ambassador, Permanent Representative to the United Nations

Even though the bilateral agreement was signed this year, we have not yet been able to make much progress, due to financial difficulties mainly. Nevertheless, it represents a valuable basis, and we shall continue negotiations in Washington for its gradual implementation. But it will take time.

We are only beginning to enter the nuclear field. I would even say we haven't entered it yet.

Atomic organization. We have no atomic commission yet, but as one lesson of this Conference I am going to suggest formally that we set up one. I will have the charters of the national authorities of the U. S., Canada, Australia, and England studied.

I believe that we shall have a Nuclear Energy Commission in about two years. We cannot do it earlier because we do not yet have the men for such an agency. I shall submit my proposal to the Ministry of Foreign Affairs, which will submit it to the President of the Republic, who will make the final decision.

Reactor and power plans. Buying a reactor is still very far off. We do not have the means for the time being. And in many sectors (for instance in the island of Mindanao, which is rich in water) we must first complete our irrigation and hydro-electric programs (we are investing $7.5-million for this in Mindanao alone).

It may be possible that later some private corporation will decide to set up a power reactor, especially near Manila, our main industrial center, which has not enough electric power. Indeed, the MERALCO (Manila Electric Co.) is thinking along these lines already. And one of my proposals to the government will be that whenever a private corporation sets up a power reactor, it should be compelled by law to give free access to it to all our interested groups. We want to conduct research in this field, but we can spend only very little for it.

There are signs of uranium deposits in several provinces, but we have not prospected them yet. One of the benefits of this conference for our men is that we heard a lot about prospecting methods, and we are going to profit considerably from this information when the time comes. The prospecting will be done by the government Bureau of Mines.

Manpower resources. I shall recommend to my government the organization of special courses in colleges and universities on nucleonics as soon as possible, with teachers from other countries, probably from the U. S.

To fill at least partially our dearth of teachers in this field, we have already sent to the U. S. half a dozen promising students (four are members of this delegation and will return to their studies at Princeton, Oak Ridge, etc. immediately after the close of the Conference). This group will later form the core of our program for training of our scientists.

PORTUGAL

JOSE FREDERICO ULRICH
Chairman, Junta de Energia Nuclear (Nuclear Energy Commission of Portugal)

The bilateral agreement with the U. S. was signed only very recently, so we haven't yet been able to get concrete benefits from it. But we expect that it will be of great help to us, in particular for the first years to come, in the field of technical help for the training of our technicians and scientists in the nuclear field.

Atomic organization. We set up, even before signing the agreement, a governmental Atomic Energy Commission. It is called the "Junta de Energia Nuclear." I am the Chairman of this Authority. The Commission receives its funds from the government, according to its needs at the time. These funds are naturally increasing yearly.

We do not ourselves set up laboratories, nor acquire facilities yet. For the time being, the Commission works in cooperation with, and uses the facilities of, another government agency, the Institute for Higher Studies at Lisbon. At the present time, some 50 students are specializing in nucleonics at this Institute. This number is

bound to grow quickly as the enthusiasm is very great amoung our young people for this kind of science.

Reactor and power plans. We do not know yet what kind of reactor we will buy, nor when and where. However, our preference would go to an equipment using natural uranium, in order to use our own resources of this mineral. Maybe the British would be the best source for such reactor, but we don't know yet.

We shall probably have a research reactor of some kind or other, a small one, in a year or two, for the further training of our specialists. And we plan to build a power reactor around 1962–1965.

As we have neither coal or oil resources, and as our water supply for hydro-electric power is very irregular (shifting between 100 and 40% according to rains, etc.) nuclear power presents a tremendous interest for our country, as we could use our own uranium resources, or those of our overseas territories (Angola, Mosambic, etc., where prospecting started in 1954).

We are at present actively prospecting our territory for uranium ore, which we know we have. We are using modern means, including aerial covering and canvassing. Provisional estimates would indicate that we should be in a position to cover the totality of our needs of electricity with our own uranium resources in one or two decades, if nuclear science continues to progress at the same pace as during the past few years.

Manpower resources. We are at present very short of trained manpower, but we are doing all we can to train new men in this new science. We have about half a dozen men studying in the United Kingdom, one man at the Argonne reactor school, a couple at the Nancy (France) school, studying uranium prospecting, and in other European special training centers. We expect to have more each year.

REPUBLIC OF CHINA

H. R. WEI
Chairman,
Republic of China Atomic
Energy Delegation to Geneva Conference

We see the bilateral agreement with the U. S. as mutual to an international agency. The bilateral stresses training of men.

Atomic organization. We have an atomic energy council that coordinates the efforts of existing universities and ministries. It predates the bilateral agreement. It consists of representatives of the ministries concerned and experts. Six of these experts were in our delegation at Geneva. The Minister of Education is chairman of the program, reflecting the fact that the present effort is most concerned with research and training.

Reactor and power plans. Formosa has lots of water power but the best two-thirds of it is already being utilized and the supply fluctuates. We have some thorium in beach sands. We especially feel that atomic power will be useful in the future, but the primary need is for the training of people and the advancement of isotope uses (we have been getting isotopes from Oak Ridge).

We plan first to acquire an experimental research reactor that will be used as a neutron source and for the production of short-lived isotopes. We're still studying the type of reactor and are about ready to submit definite recommendations to the Atomic Energy Council for the purchase of this reactor. In acquiring the reactor we will make full use of the position we occupy under the bilateral agreement with the U. S.

Manpower resources. We need to train men. We plan to send one or two men to Argonne in October and one medical man to Oak Ridge as a first step in getting more trained men for our program.

SPAIN

JOSE MARIA OTERO NAVASCUES
Vice President of the Nuclear Energy Commission

The agreement with the U. S. is extremely important to us, as it will permit us to buy an experimental reactor for the production of isotopes, the training of our technicians, and the testing of certain materials.

Atomic organization. Our government agency concerned is the Junta de Energia Nuclear (Nuclear Energy Commission). It is already an important institution for our country, with a total staff of some 1,000 people, including 80 engineers and physicists. It has set up laboratories of its own and has a budget, paid out of state funds, of 140 million pesetas, (some $3½-million) per year. It works in direct contact with industry through its advisory council, in which a majority of members stem from industry.

The Commission also gives subsidies to Spanish universities—mainly Spain and Valencia—to help them in the development of nuclear studies.

Reactor and power plans. We definitely intend to buy a reactor from the U. S. very soon. However, we want a more powerful research reactor than the one bought by Switzerland and exhibited at Geneva. For this purpose, a group of us will go to the U. S. in October and submit our preliminary specifications, in order to order the reactor later. We expect that in some 18 months we shall start installing the reactor near Madrid.

We will badly need, soon, power reactors. We calculate that in about ten years we will have exhausted our relatively poor (dry climate) potential resources in hydro-electric power. We do not have enough coal for conventional coal-burning plants. We have no oil.

But we have uranium deposits, which we started exploiting two years ago. Therefore we want to be able to use natural uranium in our future reactors. We are fairly advanced in metallurgy and can concentrate the ore domestically, or will soon be able to. We have already set up a metallurgical pilot plant for the treatment of uranium ore. We need a conventional moderator.

We do hope to start with the building of power reactors in 4–5 years from now. For the time being, we want to wait for the end of the 5-year experimentation by the U. S. AEC, and profit by their experience. In any case, the reactor that will then be chosen will have to take into consideration the special conditions of Spain, in particular our lack of water in most places.

When the time comes, the advisory committee for nucleonic power plants of the Junta will advise the government on the type of reactors needed. Then, one or several state-owned corporations will probably be set up for the erection of the plants.

I visited Harwell recently and was very much impressed by the British program of natural-uranium reactors.

Manpower resources. We have a difficult manpower problem, as we haven't enough trained physicists for

our needs. This we try to correct by giving scholarships for post-graduate studies to capable people. We have already 15 back from studies in the U. S., and have at present 6 studying.

SWITZERLAND

PAUL SCHERRER
Professor, Physics Institute,
Federal Polytechnic Institute

Only thanks to this agreement will our country be able to get the uranium it needs for the research reactor now under construction. The agreement was the solution to one of our greatest problems: for years we were trying to buy uranium, with no result. Now we bought, in 1955, 10 tons of uranium, from the U. S. and will get another 10 tons from the Belgium Congo. We have also bought 14 tons of uranium (10 tons of metal) in the U. K. This will permit us to go ahead.

We were also extremely glad to be able to purchase, at a reduced price as a result of the agreement, the research reactor now exhibited in the park of the Palais des Nations. Without this reactor, we should have lost two years.

Atomic organization. Our national atomic energy agency is the Swiss Commission for Atomic Research (Schweizerische Kommission für Atomforschung) or SKA, in which both government and industry participate. It was set up in 1946. This agency is mainly supported by industry, the government contributing some 800,000 Swiss francs (slightly under $200,000) a year to its expenses. It has already built a research cyclotron at a cost of some $60,000, plus several smaller apparatus for nuclear research.

Switzerland is one country where industry itself does much more for atomic research than the government. The latter hesitated up to now to commit themselves to any other government in this field, on account of its neutrality principle. But gradually the need to help industry in this field is being felt more in government spheres, and greater help will be forthcoming. Some years ago, I had literally to canvas the large industries to beg for some funds for atomic research. Now, and especially after this conference, the situation is bound to change rapidly.

Reactor and power plans. As a first stage, a heavy-water reactor will be erected, built practically entirely in Switzerland, at Würenlingen, 30 km from Zurich. The foundations are already well advanced, and we expect the reactor to be ready in 2-3 years.

As soon as this reactor functions, we shall start, on the same grounds, the building of a prototype power reactor.

We shall need atomic power in the future: we have no coal or oil, and our hydro-electric power resources, already well developed, (14-billion in use of 25-billion kwh total) will be exhausted in some 20 years or so.

The building of a power reactor will depend on the experiences of the coming years. If it can be demonstrated that electricity can be produced at least as cheaply as by hydro-electric plants, the semi-official public utility corporations of Switzerland (financed by cantonal governments and industry, not by the federal government) will doubtlessly be able to raise the necessary funds for the establishment of power plants. But to this day, the economy of nuclear fuel plants is too uncertain, and we shall have to fight for every cent of money we can get to build research reactors.

The reactors will be conceived in Switzerland. We have already prepared a large number of projects (the present one is number 34), and we are quite well advanced theoretically.

Manpower resources. From this angle, we are, or could be, extremely well equipped, as we are very advanced in pure science. Indeed, we started studying nuclear physics 18 years ago, and we have nearly 200 graduate nuclear physicists who came out of the Zurich Institute alone. But we lose most of them because they are not paid enough in Switzerland. The majority of them have migrated to the U. S. or England. One of my own pupils, Dr. Bretscher, is a director at Harwell, for instance. Something will have to be done soon to stop this migration; the best remedy will be higher salaries.

The universities of Basle, Berne, Zurich and Geneva also are teaching one or the other field of nuclear physics.

THAILAND

MUNI V. VEIYANT RANGSRISHT
Deputy Prime Minister;
Rector, Chulalongkorn University

The agreement is one of principle, and it will no doubt help us considerably when we are ready to get deeper into atomic power and science. But before we can go any farther than we are now, we need teachers and laboratories.

Atomic organization. Less than a year ago, we set up a National Committee for Atomic Energy, which works in connection with our National Energy Commission. We work in close cooperation with the department of mines, whose acting director-general, Mr. Vija Sethaput, is here with me. Our committee is, for the present, an administrative and theoretical body on these problems. It has no material facilities of its own. Its main work is reporting on these new problems to the Government.

Reactor and power plans. We would like to receive a reactor for Bangkok University as soon as possible, but we cannot now afford one, even at half-price. And we should be able to set up laboratories too. All this is a problem for the near future. The reactor for research would most probably come from the U. S., as we shall probably get the most favorable conditions from America.

At a later stage, we hope to set up a power reactor, for we shall be short of electricity due to the industrial development now starting in Thailand. We can use one, for we only have lignite as our main fuel, and very little oil. Atomic power would find a ready place in our development.

We don't know yet if we have sizable uranium deposits, for systematic prospecting has not started. However, there are some signs of the occurrence of uranium ore. Maybe we shall be able to do some work later in this field. We have no modern equipment yet for prospecting, although we have a few Geiger counters at the University.

Manpower resources. At present, we have only a handful of physicists. We plan to teach nuclear physics in the near future at the Chulalongkorn University in Bangkok, but we are not quite ready.

We have four or five graduate physicists doing higher studies in the U. S. at present—two are at Argonne, for example. We expect to send others.

A couple have Thai government fellowships, but for the others we must rely on help from either the U. S. (ICA, formerly FOA), or the U. N., through its Technical Assistance program.

TURKEY

BESIM TANYEL
Professor of Physics, University of Ankara

Turkey signed the agreement with the U. S. as a matter of principle, especially to be able to get, some time in the future, an inexpensive research reactor, and to benefit from the facilities offered by the U. S. for training our physicists in atomic science.

Atomic organization. We have no central agency for atomic research, although we may establish one in the future. At present, everything connected with this science is done at our two main universities, Ankara and Istanbul. Both these universities deliver certificates in atomic physics; at Ankara we have done so since 1950. At Ankara we do research on Geiger-Müller counters, and we have a project on molecular physics with high-frequency currents on the way, for instance. But we are still beginning.

Our laboratories are as yet poorly equipped for nuclear studies. Instanbul University, however, has an accelerator and is in the process of buying a cyclotron from the Netherlands.

Reactor and power plans. Our plans for the future can be summarized as follows: First, we shall purchase a small research reactor in the U. S., more or less like the one exhibited at Geneva. Much later, when we have at least 50 or 100 nuclear physicists, we shall contemplate the purchase of a power reactor. Our coal and lignite resources will be well nigh exhausted in some 25 years or so. In some 5 or 10 years, we shall know if atomic fuel is cheaper than hydro-electric plants for our country, and decide accordingly. But today, we are still learning about this new science and technique.

As to uranium deposits, we do not know yet if we have usable ones. Our Department of Mineralogy has started prospecting, but it is too early to pass judgement on such resources.

Manpower resources. As a start in our manpower development program, and thanks to the bilateral agreement, we have already sent five physicists and engineers to study in the U. S. with government scholarships. Next year we expect to send about one dozen or more for special studies. We also had a physicist training in Paris for two years, a man who did not know English, but knew French.

There is great enthusiasm among our young people for nuclear science, so we expect to have more and more specialists with time, maybe a hundred in some ten years.

URUGUAY

WALTER S. HILL
Director, Physics Institute, Engineering Department, University of Uruguay

We were glad the government signed, quite recently, the agreement with the U. S., which will permit us to develop our nuclear physics much faster.

Atomic organization. The National University (the only one in Uruguay, where all higher studies are concentrated) has already prepared a draft for the statutes of a Comision Nacional de la Energia Atomica (National Committee for Atomic Energy). This is now being studied by our Executive, the Consejo Nacional de Gobierno.

In the plan accompanying the statutes, we suggest that the Commission should be granted sufficient funds to acquire a research reactor, for training and isotope-production purposes.

Reactor and power plans. At this conference, I have already started discussing the purchase of a research reactor with some U. S. representatives. It seems that a reactor of the North-American-Aviation type would best suit our purposes, but we have taken no decision yet. Immediately after this conference, I shall go to the U. S. and continue preliminary discussions.

As to power reactors, we shall certainly need several medium-size ones in the near future. Today we are already short of electric power, and have at times to ration distribution to users. Even the large hydro-electric plants now under construction will fill the gap only for a few years. We have no coal to speak of, and although we have promising deposits of oil, the oil we could produce later will barely be enough for transportation purposes. So atomic energy appears as the best solution, as soon as it turns out to be economical enough.

Our electric lines only cover a small part of the country, and it would be very expensive to extend them sufficiently. So we contemplate the setting up of several medium-sized atomic plants where no lines exist.

We do not yet know which type of reactors we shall buy. We shall study the results elsewhere in this field before deciding.

As soon as we can prove to the government that atomic power can compete economically with conventional fuel (imported fuel oil or coal, which makes electricity very costly in our country), the government will probably buy the necessary reactors.

These will probably be set up jointly by ANCAP (Administracion Nacional Combustibles, Alcool, Petrolios—the government fuel agency) and UTE (Usinas Telefonos y Electricidad—a government agency that has the monopoly for electricity distribution and production).

Uranium ore was found in two places in Uruguay. The mineral on the surface is of rather poor content, but the area is promising. In a few months we will know better.

Manpower resources. As to manpower and laboratories, we are probably more advanced than any other Latin American state. We have several graduates studying abroad; we will send more now that the agreement will facilitate such studies. We already have quite a group of people working on nuclear subjects in several of our institutions. And thanks to the Rockefeller Foundation, which gave us $10,000 and to UNESCO's Technical Aid ($30,000 for equipment, experts and fellowships) we were able to buy valuable instruments in the U. S., so that our university institutes are now well equipped for such studies.

The main institutes, at the University of Uruguay, where nuclear studies are at present conducted, include (with director's names in parentheses): physics (W. S. Hill), endocrinology (Dr. Cervino and Dr. Morado), biophysics (Dr. Patetta), and cancer studies (Dr. Leborgne).

There is also a very well equipped privately founded laboratory studying these problems (MC^2 Laboratory, Av. 8 de Octubre, 2874, Montevideo). Private grants made it possible as a nonprofit but private institution. The government only contributed to its setting up in granting permission and dollars at the official exchange for the purchase of equipment abroad.

VENEZUELA

An interview could not be arranged with the Venezuelan delegation.

Russian Physics at Geneva

The Geneva conference provided the first real opportunity for scientists of East and West to get to know each other. Here a Brookhaven physicist who was at Geneva reports impressions of the Russians and their neutron researches

By H. PALEVSKY
Physics Department
Brookhaven National Laboratory
Upton, New York

THE INTERNATIONAL CONFERENCE on Peaceful Uses of Atomic Energy recently ended in Geneva clearly demonstrated how science can serve the cause of peace. All who participated in this scientific meeting came away with increased knowledge and appreciation of the efforts of their colleagues in other lands. From the papers presented in the heretofore classified fields of reactor physics and engineering it was obvious that scientists all over the world had been working on common scientific problems. Isolated from one another by security regulations, working completely independently, scientists solved similar problems and obtained strikingly similar results. This common experience in all countries provided the real basis for mutual understanding and trust between the delegates and representatives of the various countries.

For delegates from the West the most interesting points of the meeting were the size and scope of the Russian scientific effort. Before the Geneva meeting, Russian security regulations had extended into all scientific work connected with atomic energy and consequently practically no published work was available to western scientists even in "non-sensitive" areas of nuclear research. Such scientific work had been published freely in the West and had provided some basis for comparison of scientific potential. A very important result of the conference is that it is now possible to attempt a realistic estimate of the Russian scientific strength.

To keep perspective one should recall the impressive U. S. contribution at Geneva. This stemmed from the work of the U. S. AEC, first in establishing a sound declassification policy and second in presenting a truly representative cross section of our work in the vast fields of atomic energy and its peacetime applications. As a result, the entire world saw that the U. S. has made tremendous progress in all phases of this new field and was willing to share its knowledge and technology.

In the technical sessions the U. S. presented as many papers as the USSR, UK, and France combined. The U. S. gave details of the design and construction of each of the several power-reactor types. In the sessions on basic physics papers were presented by such leading American physicists as Bethe, Seitz, Wheeler, and Weisskopf. In the biological and medical sessions the 39 papers presented by the U. S. clearly showed that the U. S. was devoting a good part of its effort and thought to peacetime applications.

Neutron Physics

As a scientist engaged in research in neutron physics, I should like to report on Russian measurements of neutron cross sections and related constants for reactor design. This work provides a good example of the scientific effort being made in the USSR.

There are three groups actively developing equipment and measuring cross sections.

The senior group is located at the Institute for Nuclear Problems of the Academy of Sciences of the USSR some fifty miles outside of Moscow. This group is headed by Dr. V. V. Vladimirsky and works with the nuclear research reactor located at this laboratory. They have constructed fast choppers for neutron measurements in the resonance region, and have made total and fission measurements on the heavy elements. The curves of their latest work, presented by Vladimirsky at Geneva, indicate that the resolution of the equipment now in use is better than 0.1 μsec/meter, which compares very well with the 0.07-μsec/meter resolution of the Brookhaven equipment.

At this same laboratory a group presumably headed by S. J. Nikitin is using a 12-Mev cyclotron as a pulsed neutron source. This group, represented at Geneva by S. I. Sukhoruchkin, presented results on total cross section measurements of U^{233}, U^{235}, and Pu^{239} in the thermal and resonance energy regions. They have also made direct measurements of the energy dependence of the neutron multiplication, η, from thermal through the first resonance level in the fissionable materials. They used a Hornyak button-type scintillator to detect fission neutrons. This same technique had been independently developed several years ago at the Brookhaven laboratory.

A third group, working in neutron physics at the Academy of Science RFT reactor at the Lebedez Institute in Moscow, was represented at the meeting by V. I. Mostovoi and V. F. Gerasimov. Mostovoi and a group of co-workers developed and constructed the mechanical velocity selector used at this reactor. The chopper has a burst time of 4 μsec and consequently is used for measurements in the thermal and low-energy resonance regions. Gerasimov presented the results of fission and total cross-section measurements using the above velocity selector.

EAST MEETS WEST. K. V. Vladimirsky of the USSR (left) converses with H. Staub of Switzerland in the lobby of the Palais des Nations

A very interesting part of this report was the development of a fission chamber utilizing the signals from both fission fragments to obtain high discrimination against alpha pile-up.

In addition to the detailed cross-section measurements of the above three groups, the USSR presented a comprehensive set of papers on the determination of the other constants needed for reactor design calculations. One paper (*644*)* described the important method of obtaining α, the ratio of radiative-capture to fission cross sections, by mass-spectrographic methods. Three papers (*657*, *658*, *660*) were concerned with measurements of the neutron multiplication processes in the fissile materials for a thermal distribution of neutrons. One (*659*) dealt with resonance integral techniques and measurements. Neutron diffusion in moderator materials (beryllium, graphite, and water) was also discussed (*661*, *662*).

The Compton-electron magnetic analyzer described by L. V. Groshev, B. P. Adjasevich and M. A. Demidov (*651*) deserves special mention. The spectrometer is used to measure neutron-capture gamma rays of 0.3–10-Mev energy. The spectra they showed were of high resolution. In response to a question by Weisskopf of the U. S., Adjasevich showed some recent USSR results obtained with heavy elements. These data are better than any obtained thus far in the West.

The over-all impression that an experimental physicist gets from reviewing the work done by the Russians is that they have attempted nearly all the types of experiments we in the West have, utilizing methods and techniques similar to our own. This of course means that they have developed all the various kinds of equipment and gadgets that we have in our laboratories. In this respect it might be added that the equipment shown at the Russian exhibit leaves little doubt as to their capabilities for manufacturing scientific instruments.

Based on the papers presented at the technical sessions and on informal conversations with the Russian scientists I would say that in most cases their experiments do not seem to be as elaborate as ours. This fact is reflected in the numbers quoted by the Russians which for the most part have larger limits of error than our own. However, the remarkable (at first comparison) agreement between Russian results and those of the West should once and for all end questioning of Russian ability in experimental physics.

It should be added that in nearly all discussions the Russian scientists were affable and showed a well-developed sense of humor. They were willing to take criticism of their work and when differences in data arose they were extremely anxious to find the reason for such differences. Except for language, their thoughts and actions were very like their Western "colleagues'."

The Scientist in Russia

When the scientists from various delegations met at social functions some time was always spent discussing subjects other than science. It was during these discussions that we learned many interesting things about the scientist's life in the USSR, and some insight into how a country like Russia, with practically no technology 25 years ago, has made such startling progress.

There has been a great effort made in the USSR to develop and expand their educational system. It was stated that today there are universities not only in the western Russian cities but in all densely populated sections of the USSR. As large sectors of the country were developed the government provided not only primary and secondary schools, but also built new universities and engineering schools. From what one could gather in these conversations I would hazard a guess that the over-all educational plant in the USSR is as large as that in the U. S. and that university facilities are of the same order of magnitude as our own. However, the Russian system with its many Technical Hochschules is more nearly akin to the German educational system than our own.

It is also interesting to note that in contrast to the U. S. there seems to be very little connection between the universities and the research laboratories. Scientists who take university positions spend most of their time teaching, although it appears that a few scientists in the upper echelons have appointments in both research and teaching.

From many conversations it was evident that scientists are in the upper strata of the Russian society. The economic level of this group is extremely high compared to the mean level in Russia and in an absolute way seems to compare favorably with our own. In conversation with one Russian scientist, a man of forty who heads a research team in one of the laboratories, it turned out that he owns two cars and a place to vacation in the country. All scientists get two months vacation during the year. Another interesting point is that the salaries for teaching positions are higher than the salaries in the research laboratories, again pointing out the emphasis being placed in the USSR on education.

In conclusion—there is no doubt that in both the scientific and the technical phases of atomic energy the U. S. and the West generally are ahead of the USSR. However, the rapid progress made by the Russians is clear warning that if we lag behind in the training of teachers and scientists, the Russians will certainly overtake us.

* References are to Geneva papers. See p. 90 for availability.

U. S. Reactor Operating History: 1943–1954

In 12 years, the United States has operated over 25 reactors safely. Here is the record for AEC facilities, augmented by data for critical assemblies and a record of "scrams"—actions taken to prevent accidents

Why Reactors Are So Safe

The principal reasons for this successful history of operating a completely new type of device—the nuclear reactor—have been:

1. Cautious design has tended toward maximum utilization of inherent safety mechanisms and inclusion of a multiplicity of automatic control devices.

2. Operating procedures have been very carefully worked out, the operators thoroughly trained, and the plants supervised by knowledgeable personnel.

3. In most cases reactors have been thermal in spectrum with associated slow response time and have been designed to take advantage of negative temperature coefficients so as to be, in large, self-regulating.

4. In addition to the precautions in design exercised by the organizations who have constructed these reactors, the designs have been reviewed by the AEC Reactor Safeguards Committee and its successor, the Advisory Committee on Reactor Safeguards, chaired by Edward Teller and C. Rogers McCullough, respectively. Those planning to construct and operate reactors have been required to examine in detail the possible accidents to which their plants might be subject and to describe steps taken to prevent or minimize such malfunctions. In addition, the relationship of the reactor plant, and its waste products, to its environment—geology, hydrology, seismology, geography, and meteorology—are reviewed to determine the adequacy of the site, both on the basis of normal or potential hazards.

TWENTY-FIVE NUCLEAR REACTORS have been safely operated for the Atomic Energy Commission in the United States during the past 12 years, with no accidents involving contamination of off-site property or radiation injury sufficiently serious to cause lost time of personnel. A total of 606,686 hours of experience have been accumulated in operation of these units. A total of 17,799,000 man hours has been involved. These data include only AEC facilities and not the privately owned research reactor at North Carolina State College or the unit of the Department of Defense at Consolidated Vultee Aircraft Corporation, Fort Worth, Texas.

On reactors other than production facilities, a total of 1,608 million kilowatt hours of thermal power has been produced. Figure 1 shows power growth versus time. In the summaries of operating experience, described here, it has been necessary to withhold the power level of production reactors in the interests of national security.

This article enumerates the few reactor incidents that have occurred. Incidents with critical assemblies are also

By RICHARD H. GRAHAM
Division of Reactor Development
U. S. Atomic Energy Commission
Washington, D. C.

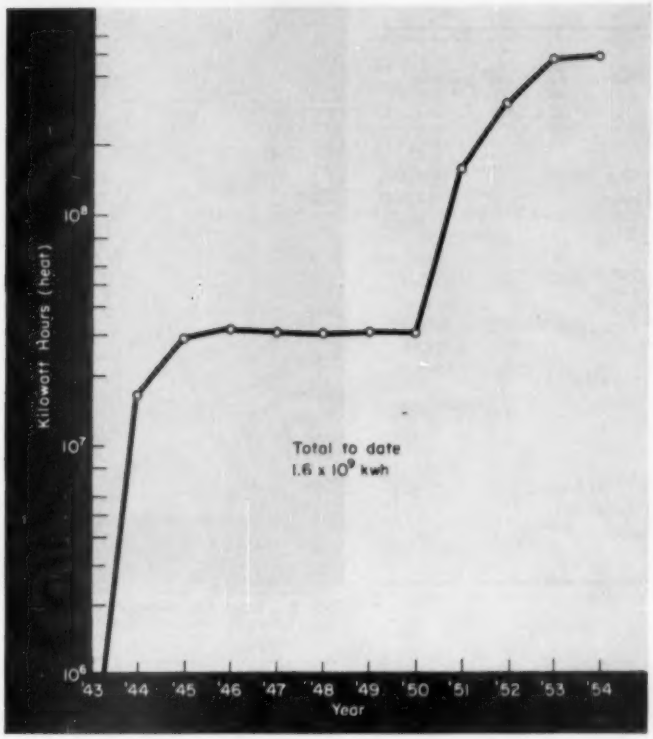


FIG. 1. Total AEC reactor power output, exclusive of production facilities

described. Records of unscheduled shutdowns are included.

Definitions

A production reactor is defined as one specifically designed and operated to produce weapons-grade nuclear fuel and is so differentiated from research and power reactors. But all three types of reactors (research, production, and power) are quite similar in mode of operation and are, as a class, divorced from the operating procedures of critical facilities.

A critical facility is a device designed to test at extremely low power (a few watts) the critical mass, neutron flux distribution and other characteristics of a flexible arrangement of nuclear fuel, materials of construction, coolant and other reactor components. Fluid critical facilities explore the critical masses of various concentrations of solutions in differing geometries. Metal critical assemblies investigate the variations in heterogeneous cores.

Reactor Incidents

The records show several reactor incidents that cannot be classed as accidents in the sense of liability or property damage external to the plant.

At Hanford, Washington, a plugged process tube allowed some fuel elements to melt and required a shutdown of approximately one month for repair.

Again at Hanford, irradiated slugs were inadvertently blown from the pile by water pressure and mistaken for cold slugs by the operators. Three men received hand doses of approximately 100 roentgens. The maximum "whole-body" dose was about 3.5 rad, well below the emergency allowable tolerance. No time was lost from the job by the personnel involved.

At the Savannah River Plant, near Aiken, South Carolina, a large quantity of heavy water was accidently jettisoned, causing large financial loss but no plant damage or personnel injury.

At Los Alamos, New Mexico, an experienced scientist involved in control-rod calibration produced a condition of supercriticality and received a dose of about 2.5 roentgens, again well within emergency limits.

These are the only reactor incidents recorded to date. Reactor data have not as yet been analyzed to yield plant operating factors from an over-all standpoint.

Critical-Assembly Incidents

However, accidents have occurred in critical facilities, which must be classed in an entirely separate category from research, production or power reactors. The single accident to date with a critical facility that involved personnel injury has cost 768 hours in lost manpower. There have been no accidents involving injury to nonemployees. There have been no fatalities. A critical-facility safety record of 21.2 hours lost time per thousand hours' operating history has been established. This is with a total operating history of 36,196 operating hours involving 14 units. A total of 1,440,000 man-hours was accumulated with a lost time rate of 0.53 hours per thousand man-hours.

There have been incidents in which critical facilities have been involved, such as the inadvertent supercriticality and rupture of a small homogeneous critical facility at Hanford while studying hazards of plutonium solutions. There was recently another solution criticality accident at Oak Ridge,

TABLE 1—Reactor Operating Data

Total operating hours	606,686
Total man hours	17,799,000
Accidents	None

Scram Record	*Personnel error*	*Equipment failure*
Total	705	2,782
Number/1,000 hours	1.16	4.59
Number/1,000,000 man hours	39.6	156

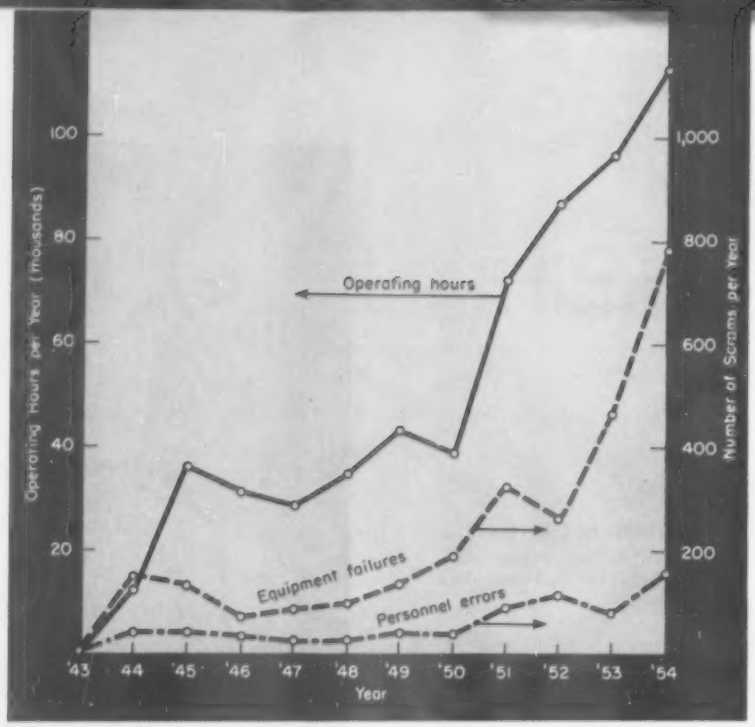


FIG. 2. Total AEC reactor operating history, including production facilities

Tennessee, involving aqueous solutions of uranyl nitrate. These accidents caused no lost time of personnel or damage to other than plant property.

This accumulation of data of critical facilities does not take into account those specifically designed for weapons studies. Two fatalities occurred early in the weapons criticality field; there have been a number of minor accidents since in which no injuries were sustained. The pioneering work done by Los Alamos in the weapons criticality field has paved the way to still safer design and operation of reactor criticality facilities.

Scram Records

A measure of the ease of operation of a reactor or a critical facility is the number of scrams, or unscheduled shutdowns, encountered during operation.

Scrams are initiated deliberately by the operator on the very rare occasions when he perceives a situation that he judges hazardous.

In practically all cases, scrams are produced automatically by one of a multiplicity of protective devices, and in most cases by the fail-safe nature of the protective devices themselves. Many circuits are designed so that, for example, the failure of a vacuum tube in a power measuring circuit will scram the reactor. Scrams are usually triggered by such minor malfunctions.

Most reactors are automatically protected by two low-range power-level channels during startup, by two high-range and one log-power-level channel during operation, and by one or more time-rate-of-change-of-power-level channels, plus such other measurements as coolant flow, temperature and radioactivity, various structure temperatures, and interlocks against personnel entering high-activity areas. Experience is indicating that a multiplicity of protective devices is overconservative. Improved design is allowing great reduction in control devices and instrumentation.

Figure 2 and Table 1 show operating histories and number of scrams chargeable to personnel error and equipment failure. Most of the personnel error scrams are due to inattention when operating close to the trip level of one of the protective channels. Figure 3 and Table 2 show the same data for critical facilities. Figure 4 demonstrates that the number of scrams per thousand hours of reactor operation chargeable to equipment failure is low and remains fairly constant; about one per 300 hours. The constancy is probably due to the gradual addition of new and better types of instruments. The personnel error rate of about one per 1,000 hours has improved with increasing operator experience.

This good safety history is somewhat dependent on the use of thermal reactors. The average neutron lifetime in thermal reactors is approximately 10^{-3} sec, whereas it is approximately 10^{-8} sec for a fast assembly. The neutron lifetime governs the minimum period of the reactor, thus controlling the maximum possible rate of power-level increase.

This relationship does not mean that fast reactors will not play an important part in reactor development. They may indeed prove to be the ultimate type. An advisedly cautious approach was made, however, with the initial utilization of thermal reactors. Two fast reactors, Clementine at Los Alamos and the Experimental Breeder Reactor of Argonne National Laboratory, have been successfully operated.

Comparison

Why is the reactor record better than that of the critical facilities? One might illustrate the difference between reactors and critical facilities by an analogy to the field of aircraft development. Operating a critical facility is quite similar to flying an experimental aircraft that has never been flown before. Thus, operations must be done with extreme caution and cannot be done without some hazard. This explains the higher accident frequency. After every test flight of each of the experimental aircraft, modifications are

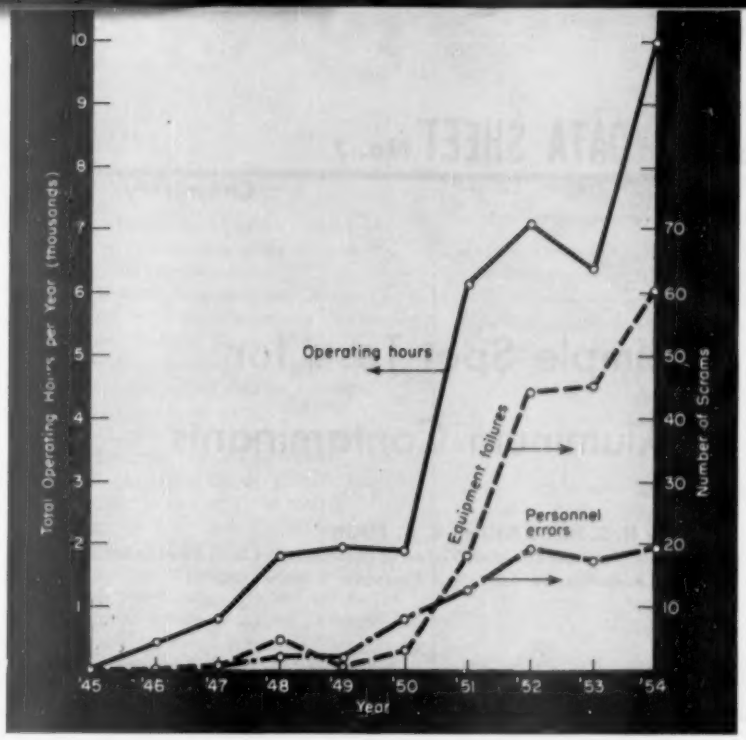


FIG. 3. Nine-year operating history of crtiical facilities, with weapons facilities excluded

TABLE 2—Critical Facility Data, Excluding Weapon Facilities

Total operating hours	36,196
Total man hours	1,440,000
Accidents	1
Personnel injured in accidents	4
Lost man hours	768
Accident rate	
Lost man hours/1,000 operating hours	21.2
Lost man hours/1,000 man hours	0.53

Scram Record	*Personnel error*	*Equipment failure*
Total	85	177
Number/1,000 hours	2.37	4.88
Number/1,000,000 man hours	59.0	123

usually made, and the pilot will therefore again be testing an incompletely known aircraft. However, most reactors might be likened to proved aircraft whose characteristics are better known.

Aircraft accidents happen more frequently at take-offs and scheduled landings than while operating in the air. Reactor accidents are likewise more probable during startup. Thus, a higher accident rate can be expected from those reactors that are started up and shut down quite frequently, as in the case of some research reactors. Also, good safety records can be anticipated with most nuclear power plants, where the operating criterion is the highest load factor obtainable.

Citations

Operating standards of the industry as a whole are good. But three organizations may be cited for superiority in specific practices.

1, 2. Brookhaven National Laboratory and Navy-Westinghouse Submarine Thermal Reactor Prototype Project for their operator training programs.

3. Phillips Petroleum Company, operator of the Materials Testing Reactor. Phillips' problem is complicated by constant introduction of new experimental devices into the reactor for engineering tests. Phillips has organized an internal Reactor Safeguards Committee comprising those skilled in the allied fields of reactor technology. This committee must thoroughly investigate the interaction of any experiment upon the reactor itself and pass on its safety.

4. Argonne National Laboratory, the staff of which has developed a thorough testing program of all of the reactors' automatic and manual safety control devices by actual generation of a reactor characteristic. This characteristic is used to check operation of each of the safety channels. This is done during the startup following weekly scheduled shutdowns.

The information on which this article is based was developed by the response of AEC reactor operators to a questionnaire prepared by E. A. Lamke, Division of Licensing, AEC, D. F. Hayes, Safety and Fire Protection Branch, AEC, and the writer. The writer wishes to express his appreciation to E. A. Lamke and A. E. Gorman for their helpful comments on this article and to the many contractor personnel for their laborious compilation of the data.

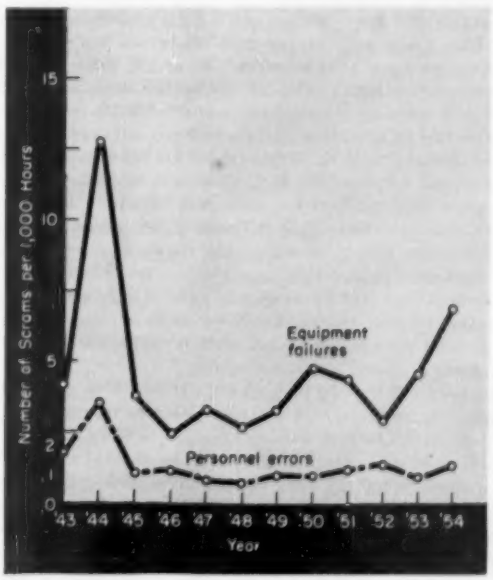
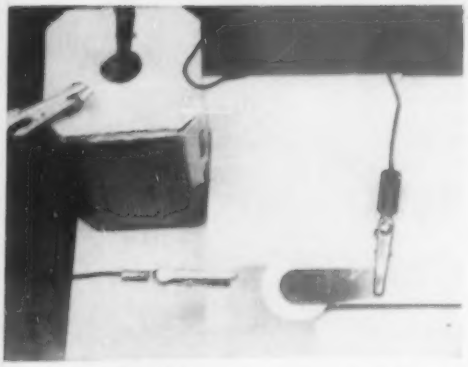


FIG. 4. Reactor scrams per thousand hours operation



SPOT-TEST setup for electrographic and colorimetric tests

Simple Spot Tests for Aluminum Contaminants

By H. S. HILBORN and R. C. PUGH

Pile Materials Division, Technical Division, Savannah River Laboratory
E. I. du Pont de Nemours & Company, Augusta, Georgia

Preparation and Properties of Reagents

Electrolytes

Acetic acid: 10%- and 5%-by-volume solution in water
Nitric acid: 0.1*N*, 1*N*, and 8*N* solutions
Potassium nitrate: 10%-by-weight solution in water
Potassium sulfate: 5%-by-weight solution in water

Indicators*

Cacotheline (saturated aqueous solution): Reacts with acidic stannous solutions to produce violet color. Other reducing ions, solutions, or compounds should be absent to assure specific test. Certain oxides and ions also interfere, e.g., colored metallic ions (arsenic, antimony, molybdenum, and uranium)

Dimethylglyoxime (1% by weight in ethyl alcohol): In neutral or acetic acid solutions, produces red color with nickel. Large amounts of oxidizing substances and iron and copper may interfere

Diphenylcarbazide (1% by weight in ethyl alcohol): Gives violet to blue color with mercury in weakly acid solutions. Chlorides and iron, copper, and nickel interfere in neutral or weakly acid solutions. In 8*N* nitric acid, test is specific but sensitivity is greatly reduced. Also gives violet color with molybdenum. Should be made up fresh each day

o-Tolidine solution (0.1 gm *o*-tolidine and 0.5 gm ammonium thiocyanate in 5 ml acetone): Blue color with copper and red-brown with iron. Mercury and strongly oxidizing metal salts interfere. Should be made up fresh each day

p-Dimethylaminobenzylidenerhodanine (saturated solution in ethyl alcohol): Red-violet with mercury. Large amounts of chloride interfere. Copper may interfere with test in neutral or acetate-buffered solutions

Potassium thiocyanate (10% by weight in water): When used with 8%-by-volume hydrochloric acid solution and 25%-by-weight solution of sodium thiosulfate in water, gives pink to deep red with molybdenum. If solutions are added slowly with moderate time lapse between additions, blue color may develop. Mercury and other metals or compounds that consume thiocyanate interfere. Certain acids form complexes with molybdates and interfere

Potassium ferrocyanide (3% by weight in water): Blue with iron and red-brown with uranium; test for one is interfered with by other. Copper and other metals that form colored compounds with ferrocyanide also interfere. Strong reducing agents turn iron compound white

Potassium iodide (10% by weight in water): Gives yellow color with lead. Mercury, copper, tin, and any material that produces free iodine interfere. Indicator solution should be colorless

Rubeanic acid (dithio-oxamide) (0.5 gm in 100 ml of ethyl alcohol; of this solution, 5 ml are diluted to 100 ml with water): Gives olive-green to black spot with copper. Nickel interferes

Quinalizarin solution (saturated ethyl alcohol solution): Gives blue color with magnesium. Aluminum may interfere if alkali concentration is not sufficient

* For information on sensitivities of indicators, and interfering ions, compounds, etc., see bibliography references.

SINCE CORROSION of aluminum components in a nuclear reactor may be dangerous and expensive, it is essential that harmful inclusions be identified and traced to their source. The tests reported here for impurities in aluminum combine electrographic sampling (*1–4*) and colorimetric spot tests (*5*).

Colorimetric spot tests, well established methods for qualitative analysis, are now a recognized field in microchemistry. Feigl (*5*) lists over 200 spot tests for over 40 metals, including rare-earth elements. Electrographic sampling is a spot-testing innovation; it has been applied recently (*1–4*) to identifying both metallic and nonmetallic constituents in alloys.

The reagents required for the tests described here are, in most instances, those described by Feigl. The equipment, consisting of clips, wire, 6-volt dry cell, cathodes, and filter paper, is compact and portable. Tests are easy and convenient, facilitating inspection in the field. For information on indicator sensitivities, interfering ions, etc., see references.

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Spot-Test Procedure

1—Area of aluminum to be tested is cleaned, if necessary using soap and water, alcohol, or acetone

2—Sample to be tested is made anode of galvanic cell by connecting it to positive terminal of 6-volt dry cell. Adequate connection is made by alligator clip or by resting specimen on plate connected to dry cell

3—Prepare cathode by connecting negative terminal to stainless-steel or aluminum electrode of proper size and shape to fit area to be tested

4—Prepare pad of 2–4 thicknesses of Whatman No. 50 filter paper

5—Moisten pad with electrolyte, which should penetrate all layers of pad and cover an area at least as large as that to be tested

6—Place moistened pad on test area and cathode on top of it. Hold cathode without movement so that it exerts steady pressure against pad and specimen. Current flow through pad causes metal ions to leave specimen and be deposited in pad

7—After 30–60 sec, remove cathode and pad; pad now contains "negative" of test area

8—Develop negative by spotting exposed surface of pad with proper indicator to form characteristic colored precipitate or complex with metal ions removed from specimen surface

Precautions and Suggestions

1—So that the tests be satisfactory, it is necessary that: (a) all electrical contacts be good; (b) moistened filter pad be in good contact with test area; (c) cathode be in contact with pad over test area; (d) sufficient time be allowed for ion transfer to take place; (e) in case of pits, indentations, and pinholes, electrolyte fill cavity before test is started

2—In some instances, good results are obtained by mixing electrolyte and indicator before passing current through cell

3—Increased current flow usually makes test more positive by causing more metal ions to collect in filter pad; optimum time depends on individual case and is affected by size and distribution of inclusions

4—Amount of pressure applied to cathode and pad has some effect; moderately heavy finger pressure is best when using filter pad of type described; pressure should be constant with no movement of cathode

5—Cross check on results, using another test or indicator if available, is desirable

Specific Tests for Contaminants

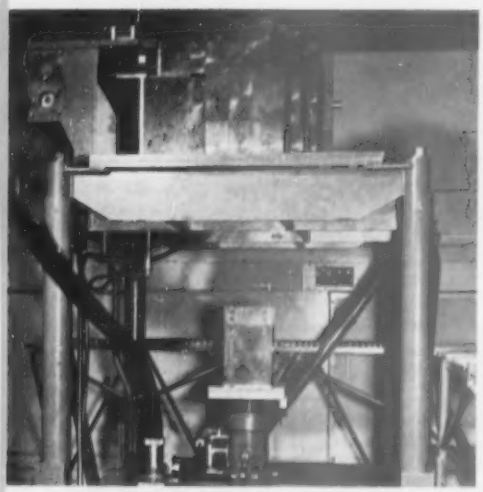
Contaminant and electrolyte	*Indicator and color for positive test*	*Comments*
Iron inclusions (K_2SO_4)	Potassium ferrocyanide (light to dark blue) or *o*-tolidine solution (Cu—blue; Fe—red brown)	Successful in identifying iron inclusions in tubing, bar stock, and vessels. With ferrocyanide, depends on amount of iron present and time of current flow; with *o*-tolidine, Cu and Fe can be detected simultaneously if they occur discretely some distance from each other
Lead (10% acetic acid or 0.1*N* HNO_3)	Potassium iodide (yellow)	Useful in testing for removal of powder used as lubricant on extruded stock and in detecting inclusions in tubes
Magnesium (K_2SO_4)—test 1	Quinalizarin solution (red-violet or red indicates Al; blue, Mg)	After spotting filter pad with indicator, pad is held over mouth of bottle of concentrated ammonium hydroxide until indicator turns blue; then over glacial acetic acid until indicator turns pink-lavender
Mg (K_2SO_4)—test 2	Quinalizarin solution	Follows same general procedure except that after spotting with indicator, sufficient sodium hydroxide is added to dissolve aluminum hydroxide and form aluminate ion; solution has faint blue tint; insoluble magnesium hydroxide remains in place and retains darker-blue color indicating Mg. Both tests useful on tubes and other extruded stock on which Mg was lubricant and on Mg-Al alloys
Mercury (K_2SO_4 and HNO_3)	Diphenylcarbazide (deep blue to purple) or *p*-dimethylaminobenzylidenerhodanine (red-violet)	Strongly recommended that this test, because of severe attack on specimen, be last applied. Try electrolytes in order: K_2SO_4, 1*N* HNO_3, and 8*N* HNO_3. Test is only moderately successful since it is difficult to dissolve Hg (*6*, *7*) without seriously attacking specimen or cathode
Molybdenum in "Molykote"—molybdenum disulfide (0.1*N* HNO_3 or K_2SO_4)	Hydrochloric acid, potassium thiocyanate, and sodium thiosulfate (pink to deep red or blue); or diphenylcarbazide (lavender to deep purple)	Successful with Molykote used as lubricant on hot-pressed Al pieces. First indicator consists of reagents added in order listed; color depends on time intervals between addition of each reagent
Nickel plating (K_2SO_4 or 10% acetic acid)	Dimethylglyoxime (bright red)	Satisfactory for determining if corrosion pit or indentation has penetrated through Al sheath to nickel plating on underside
Tin (5% acetic acid)	Cacotheline (lavender to purple)	Detects remnants of tin solders left on Al sheeting after corrosion testing
Copper flash on stainless steel (K_2SO_4)	Rubeanic acid (dithiooxamide) (olive-green to black)	Ideal for identifying very thin copper plating on stainless steel. Rubeanic acid must be used since Fe, Cr, and Ni interfere with other indicators
Copper inclusions (K_2SO_4)	*o*-Tolidine solution (light to dark blue) or rubeanic acid (olive-green to black)	Identifies copper inclusions in Al tubing, bar stock, and fabricated vessels
Uranium in U-Al alloys (KNO_3)	Potassium ferrocyanide (brown)	Not satisfactory if alloy has been treated to produce protective layer of aluminum oxide on surface
Uranium exposed in pits and pinholes in Al sheath (10% acetic acid)	Potassium ferrocyanide (brown stain)	For determining if clad U is exposed

TWO LABORATORIES that contain remotely controlled assemblies are called Kivas after ceremonial chambers of Pueblos

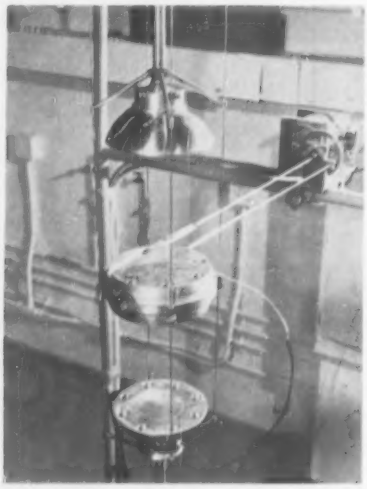
CONTROL ROOM is in main laboratory building located about one-quarter mile from each Kiva. Note use of television

Godiva,

By H. C. PAXTON
Los Alamos Scientific Laboratory
University of California
Los Alamos, New Mexico

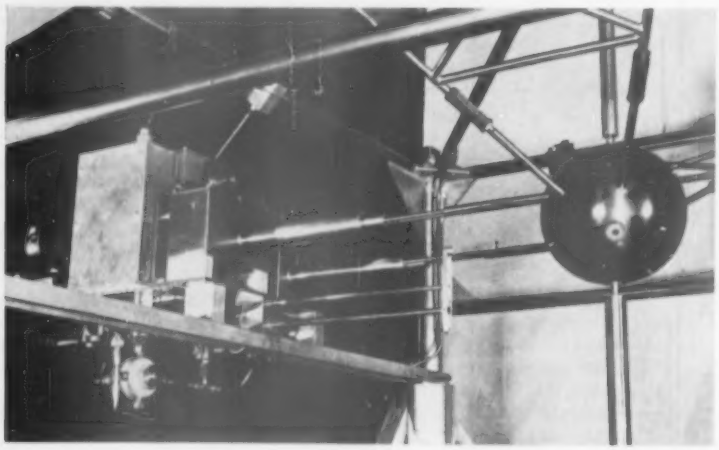


"TOPSY," IS OLDEST critical assembly, a small U^{235} metal core surrounded by a thick reflector of normal U metal. Safeties drop a section of core and reflector and shift another large block of reflector away from its normal operating position to make system safe to approach. Control rods of normal U move in channels through reflector. Topsy has been operated with Pu core



"JEZEBEL," IS NEWEST critical assembly, bare Pu without a reflector. Under operating conditions sections are brought together to form smallest, simplest critical system there is. A Pu control rod rides in channel through sphere. After its characteristics are determined as completely as is practicable, it is expected that this assembly will be dismantled

GODIVA OUTDOORS and hoisted about 25 ft to minimize room-scattered neutrons



"GODIVA," IS WORKHORSE of Los Alamos critical assemblies, bare U^{235}. It is much like bare Pu system. It is shown here in normal-U mockup

Delayed Neutrons from Fast-Neutron Fission of U^{235}, U^{238}, Pu^{239}, and Th^{232}

U^{235} (99.9%)		U^{238} (99.97%)		Pu^{239}		Th^{232}	
Period, $\tau_{1/2}$ (*sec*)	*Relative abundance*, a_i/a	*Period*, $\tau_{1/2}$ (*sec*)	*Relative abundance*, a_i/a	*Period*, $\tau_{1/2}$ (*sec*)	*Relative abundance*, a_i/a	*Period*, $\tau_{1/2}$ (*sec*)	*Relative abundance*, a_i/a
54.3 ± 0.9	0.036 ± 0.006	53.0 ± 1.7	0.011 ± 0.003	53.7 ± 3.6	0.037 ± 0.016	54.0 ± 1.0	0.033 ± 0.003
21.7 ± 0.8	0.210 ± 0.019	22.0 ± 0.6	0.128 ± 0.013	22.9 ± 1.1	0.265 ± 0.037	22.0 ± 0.5	0.133 ± 0.015
5.87 ± 0.17	0.192 ± 0.027	4.94 ± 0.10	0.182 ± 0.018	6.11 ± 0.24	0.193 ± 0.019	6.2 ± 1.0	0.172 ± 0.050
2.18 ± 0.07	0.409 ± 0.022	1.77 ± 0.04	0.405 ± 0.017	2.14 ± 0.06	0.378 ± 0.013	2.1 ± 0.4	0.458 ± 0.055
0.46 ± 0.03	0.135 ± 0.008	0.39 ± 0.03	0.240 ± 0.015	0.40 ± 0.03	0.120 ± 0.007	0.52 ± 0.1	0.169 ± 0.025
0.126 ± 0.018	0.018 ± 0.004	0.117 ± 0.015	0.034 ± 0.008	0.15 ± 0.05	0.007 ± 0.004	0.18 ± 0.02	0.035 ± 0.010
Absolute yield (neutrons/fission)							
0.0173 ± 0.0007		0.044 ± 0.003		0.0067 ± 0.0003		0.063 ± 0.006	

Topsy, Jezebel . . .

Critical Assemblies at Los Alamos*

Systems of bare fissionable metal made critical by remote assembly provide valuable information basic to fast-reactor design. Results of studies of delayed neutrons from fission are also given here

SIMPLE CRITICAL ASSEMBLIES used at Los Alamos have provided valuable information about fast-neutron systems. They've also served as a source of 50-μsec bursts of $\sim 10^{16}$ neutrons for instantaneous irradiations in studies of delayed neutrons from fission.

Critical Assemblies

The Los Alamos critical-assemblies group is located a few miles from the town of Los Alamos in Pajarito Canyon. The laboratories, control room, and some of the critical assemblies are shown in the photographs on p. 48.

The remotely-controlled assembly machines are of two types: simple but flexible machines for nuclear safety tests, and more specialized, but still simple, machines for the operation of semipermanent critical assemblies.

The over-all reason for our interest in the characteristics of elementary, fast-neutron critical assemblies is to check results of detailed calculations by modern high-speed computers. If discrepancies between predictions and observations can be eliminated, there will be increased confidence in calculated characteristics that are not readily observable in the laboratory (*1*).

The experimental quantities that are useful for checking calculations include critical masses, and results of traverses by threshold neutron detectors. For uranium assemblies, experiment and theory agree except in a few extreme cases (*e.g.*, at low U^{235} concentration). For plutonium systems, however, small but significant discrepancies call for a revision of the plutonium parameters which are used in calculation.

Reactivity Booster

Godiva, the bare U^{235} semipermanent assembly, has been equipped with a reactivity booster that takes it rapidly from slightly above delayed critical to slightly above prompt critical.

A U^{235} slug is shot into the assembly and stopped near its most effective location. When system is a bit above prompt critical, the fission rate rises extremely rapidly, the uranium heats, expands, thus dropping the reactivity enough to terminate the fission burst. Thus, a potentially run-away burst is stopped by thermal expansion. With a typical Godiva burst the initial rise in fission rate is exponential with a period of about 15 μsec and continues to a maximum power level of nearly 10^9 watts, then falls off in a manner similar to the buildup. The burst is about 50-μsec wide at half-height, and the energy developed is that of 10^{16} fissions or about 100 watt-hrs. Typical bursts are shown in Fig. 1.

Godiva bursts show a curious effect due to room-scattered neutrons. The

* Based on a talk presented at the June, 1955 meeting of the American Nuclear Society.

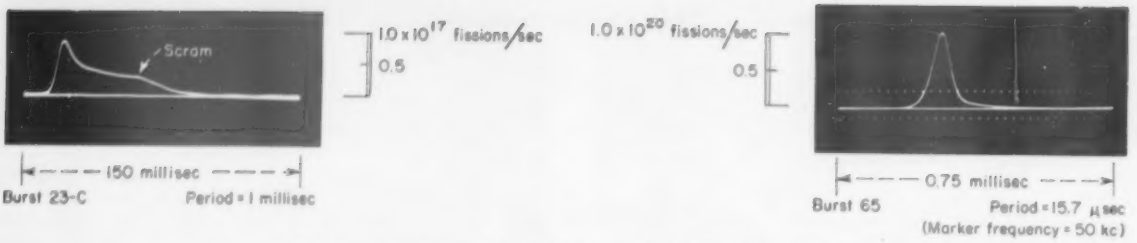


FIG. 1. Typical bursts from Godiva used with reactivity booster

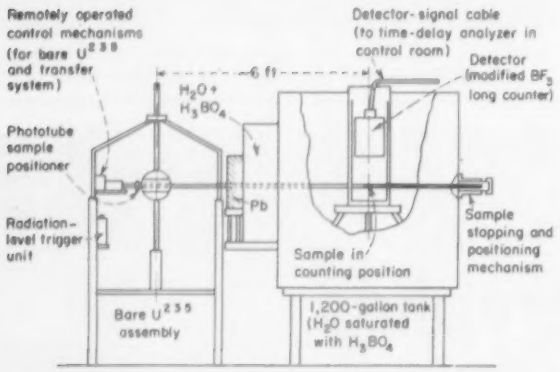

Remotely operated control mechanisms (for bare U235 and transfer system)
Detector-signal cable (to time-delay analyzer in control room)
6 ft
Detector (modified BF3 long counter)
H2O + H3BO4
Phototube sample positioner
Pb
Radiation-level trigger unit
Sample stopping and positioning mechanism
Sample in counting position
Bare U235 assembly
1,200-gallon tank (H2O saturated with H3BO4

FIG. 2. Fissionable specimens are transferred from point of irradiation within Godiva to heavily shielded counter in 0.05 sec. Multichannel time-delay analyzer (2) gives delayed-neutron activity versus time as shown in Fig. 3

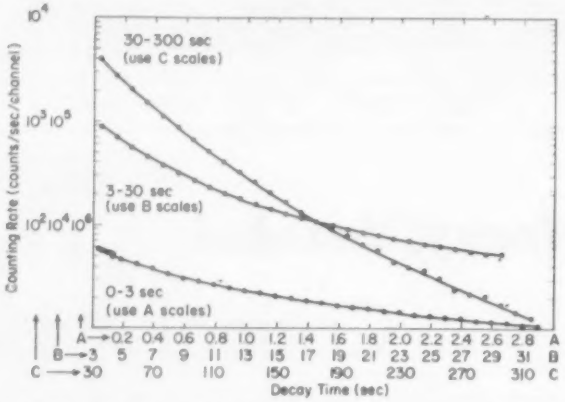


FIG. 3. Delayed neutron decay following prompt-burst irradiation of 99.9% U^{235}. These are the cumulative data from 20 irradiations of 3-gm sample. Least-squares fit to data (curve) gives U^{235} delayed-neutron groups listed in table on p. 49

shape of the trailing edge of a burst should be sensitive to short-period delayed neutrons, and, in fact, bursts obtained with Godiva indoors do appear to be influenced by neutrons delayed the order of a millisecond. As this effect disappears with Godiva suspended outdoors, it can be attributed to neutrons scattered back from the laboratory walls.

Delayed-Neutron Studies

An example of the use of Godiva bursts is a study of the periods and relative abundances of delayed neutrons from various fissionable materials conducted by G. R. Keepin and T. F. Wimett. See Figs. 2 and 3.

Figure 3, supplemented by data from a long steady irradiation, may be resolved into a set of delayed neutron periods and relative abundances.

Periods and abundances of delayed neutrons from fast-neutron fission of the principle fissionable elements as determined by Keepin and Wimett are given in the table on p. 49. These do not include ultra-low-yield groups that have been reported with half-lives of 3, 12, and 125 minutes and yields per fission of 5.8×10^{-6}, 5.6×10^{-10}, and 2.9×10^{-10} (*3*).

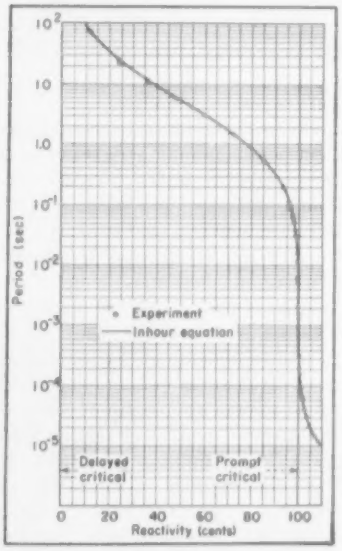


FIG. 4. Godiva period as a function of reactivity in cents

Results of Godiva reactor-period measurement show a spectacular decrease in period near prompt critical, as the influence of delayed neutrons drops out. (See Fig. 4.) This is evidence against the existence of a delayed neutron period in the few-millisecond range.

Briefly, the data for U^{235} and Th^{232} are similar to the periods and relative abundances reported for U^{235} by Hughes and his co-workers (*4*), and for U^{238} the shorter periods are more predominant. Data of this type are basic to the problem of reactor control.

* * *

Some of the people responsible for the work to which I have referred—people whose names I hope you will see on an increasing number of declassified publications are: Leon Engle, Glen Graves, Jim Grundl, Gordon Hansen, George Jarvis, Grant Koontz, Gus Linenberger, John Orndoff, Rolf Peterson, and Roger White.

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How Radiation Changes Polymer Mechanical Properties

An understanding of the mechanisms by which radiation-induced crosslinking and cleavage change the mechanical properties of plastics and elastomers helps in choosing materials for use in radiation fields and points the way toward using radiation to improve polymer properties. Here is how the radiation-altered molecular structure changes the properties

By C. D. BOPP and O. SISMAN
*Oak Ridge National Laboratory**
Oak Ridge, Tennessee

HIGH-ENERGY RADIATION alters the molecular structure of plastics and elastomers by crosslinking and cleavage —chemical changes. Consideration of the mechanisms of deformation explains how these chemical changes affect the mechanical properties.

Radiation Effects

All elastomers tested were hardened by crosslinking—with the exception of butyl rubber and Thiokol, which were softened by cleavage. Sensitive properties for crosslinked elastomers are tensile strength and breaking elongation, as well as hardness. For cleaved elastomers, the compression set is a very sensitive property. Stress relaxation of elastomers that are strained during irradiation is very sensitive for both groups.

For plastics also, direction of property changes is governed by whether crosslinking or cleavage is predominant. Crosslinking increases Young's modulus, tensile strength, and Rockwell hardness—but decreases elongation. Cleavage produces softening and a decrease in strength (*1–3*).

Deformation Mechanisms

High-polymer molecules are in the form of linear chains, which are sometimes crosslinked to a three-dimensional network. Elastomers differ from plastics in having weaker van der Waals forces. In plastics, the forces are strong enough to maintain the solid state in the absence of stress. In elastomers, the forces are weak as in a liquid—the solid state is maintained only by a few primary-valence crosslinks that form a loose network.

It is convenient to consider two mechanisms of deformation, "ordinary elasticity" and "high elasticity" (*4*). For polymers, it is customary to express ordinary elasticity in terms of a spectrum of retardation times, τ (*5, 6*).

It is rarely possible to fit experimental data with only one value of τ, so it is

* Operated for the U. S. Atomic Energy Commission by Union Carbide and Carbon Corp.

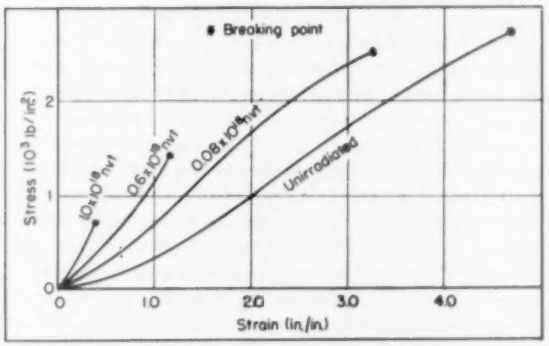


FIG. 1. Stress-strain curves for reactor-irradiated NYLON-FM-10,001. 1 nvt is equivalent to 1.0×10^{-9} rad

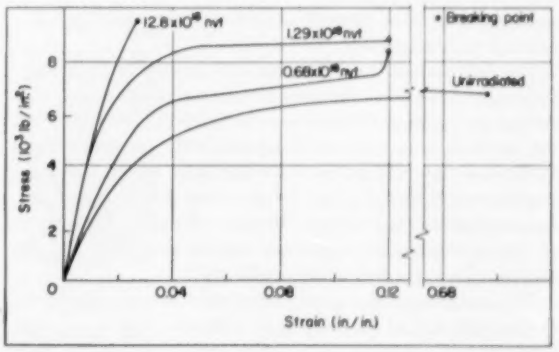


FIG. 2. Stress-strain curves for reactor-irradiated NATURAL RUBBER. 1 nvt is equivalent to 0.6×10^{-9} rad

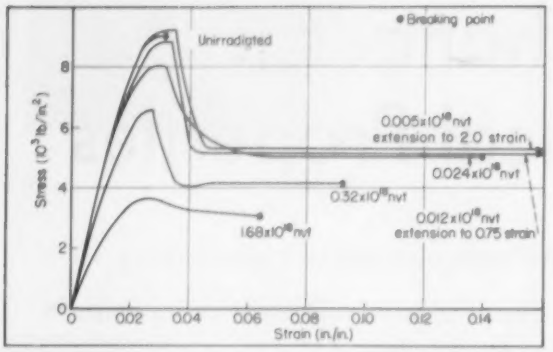


FIG. 3. Stress-strain curves for reactor-irradiated VINYL CHLORIDE ACETATE. 1 nvt is equivalent to 2.5×10^{-9} rad

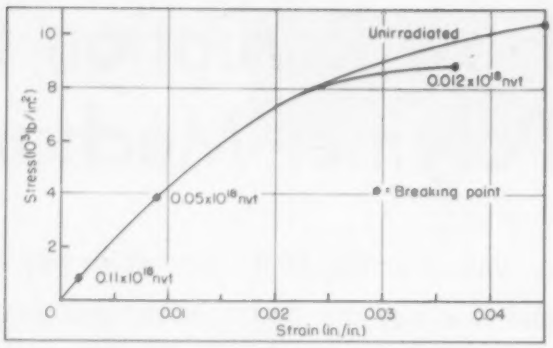


FIG. 4. Stress-strain curves for reactor-irradiated LUCITE (methyl methacrylate). 1 nvt is equivalent to 0.7×10^{-9} rad

customary to use a smooth distribution of values. The distribution of retardation times is often sensitive to the rate of dissipation of frictional energy (7), and thus may be dependent on the specimen's dimensions. On the other hand, the free volume (8) may be important, and for this reason distribution of retardation times is usually sensitive to temperature.

At very low rates of straining, "viscous flow" is appreciable in many plastics; even at higher rates of straining, viscous flow may become appreciable if the yield stress is exceeded. As in Fig. 1, the value of the yield stress is often apparent from a change in slope of the tensile curve.

A qualitative explanation of how radiation affects the mechanical properties of high polymers is given by considering only two processes—crosslinking and cleavage. The effect of crosslinking is to tend to impede viscous flow, and to increase the retardation times. The equilibrium value of Young's modulus for high elasticity is given by the kinetic theory as directly proportional to the concentration of crosslinks (9)

$$E = AkT/V \qquad (1)$$

Measured values of dynamic Young's modulus for certain elastomers may not very closely approach the equilibrium value.

Cleavage has the effect of reducing the yield stress for viscous flow. The equilibrium value of Young's modulus for high elasticity is decreased by cleavage since the number of crosslinks is reduced. The retardation times for plastics not initially crosslinked are often not changed much by cleavage.

Materials usually exhibit more than

Comparison of Test Methods

In the tensile test on plastics (10), *a complete stress-strain curve is recorded. Three characteristic parameters of the curve are:* (a) *initial slope or Young's modulus,* (b) *maximum stress or ultimate strength, and* (c) *maximum strain or breaking elongation. As shown in Fig. 1, for Nylon the ultimate strength is also the yield strength, and therefore is nearly independent of the rate of loading. Even if the yield strength is not well-defined but the slope of the latter portion of the curve is small (as in Fig. 4 before irradiation), the ultimate tensile strength is not very sensitive to loading rate. For this discussion, the ultimate strength is taken as approximately independent of loading rate.*

The Izod impact test (11) *measures the sum of the energy that would be required for breaking without deformation, and the energy required for deformation.* For plastics that are not much deformed by the impact test, the impact-strength ranking of different polymers is the same as the ultimate-tensile-strength ranking; for plastics that are deformed, the impact-strength ranking is higher* (1). *Usually, the amount of deformation in the impact test may be correlated with the amount of viscous flow in the tensile test.*

The maximum radiation exposures studied were insufficient to crosslink any of the more rigid polymers very much, and their Young's moduli were little changed.† For those more rigid plastics in which the predominant radiation effect is cleavage, Young's modulus often is not very sensitive to the molecular weight and thus is not much changed by cleavage. A more sensitive measure of cleavage for Hookean plastics is the strength decrease, which is measured nearly equally well by any of the following: the ultimate tensile strength, the shear strength (12), *the impact strength, or the breaking elongation* (1).

For the nonrigid plastics in which crosslinking is predominant, Young's modulus is greatly increased. The impact strength and the breaking elongation are even more sensitive to crosslinking than Young's modulus, since these properties are sensitive to the amount of viscous flow for nonrigid plastics.

A very sensitive measure of the Young's modulus is given by the vibration test (13). *There usually is small variation between different specimens of the same polymer, and the limit of sensitivity is set only by the uniformity of the dimensions of the test specimens. In addition to the Young's modulus, the internal friction is measured by the vibration test. The internal friction is relatively insensitive to crosslinking during the early stages of crosslinking, but it sometimes increases as the crosslinking process approaches completion.*

* If there were no deformation (as with ceramics), it would be possible to fit the fragments together to obtain the pretest dimensions.

† A more sensitive measure of crosslinking is given by the change in solubility in organic solvents.

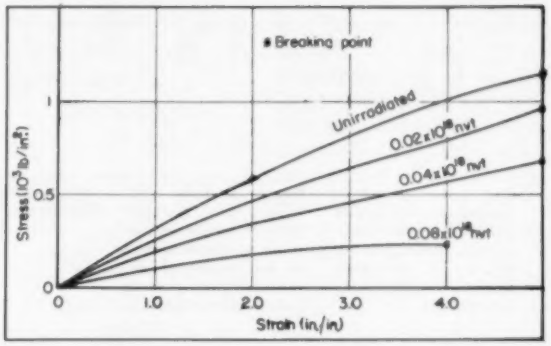


FIG. 5. Stress-strain curves for reactor-irradiated BUTYL RUBBER GR-I-50. 1 nvt is equivalent to 0.6×10^{-9} rad

one deformation mechanism (*9*), and the relative prominence will depend on the strength of the van der Waals forces (on the chemical structure), on the amount of crosslinking (a large amount of crosslinking tends to impede viscous flow and high elasticity), and on the temperature. This discussion is limited to room temperature (25° C).

For example, take nylon, as shown in Fig. 1. Before irradiation, the initial portion of the tensile curve is nearly linear (obeys Hook's law), and the deformation is mostly by ordinary elasticity although there may be a small component by viscous flow. The latter flat portion of the curve represents deformation largely by viscous flow. The yield stress at which viscous flow becomes predominant is roughly equal to the ultimate strength. The radiation effects are those described as characteristic of crosslinking. Crosslinking of elastomers is typified by the tensile curves of natural rubber, as shown in Fig. 2. Before irradiation, the deformation is mostly by high elasticity. The tensile curve of natural rubber proves even more radiation sensitive than that of nylon. After long irradiation, both natural rubber and nylon acquire a rigidity comparable with that of glasses—so care must be exerted in handling to avoid breaking specimens.

Different behavior is shown in Fig. 3 for vinyl chloride acetate polymer. Here the yield stress for viscous flow is decreased. Figure 4 for polymethylmethacrylate shows no abrupt transition between ordinary elasticity and viscous flow; however, probably as in Fig. 1 the flatter portion of the tensile curve is largely by viscous flow. As in Fig. 1, the yield stress is decreased. Figure 5 shows that butyl rubber is softened; eventually it is changed to a tarry fluid.

Young's modulus may be decreased by irradiation for some polymers but increased for others. This is explained by the differences in the relative prominence of the crosslinking and cleavage processes for different polymers. For nylon and natural rubber, the predominant radiation effect is crosslinking; for vinyl chloride acetate polymer, polymethyl methacrylate, and butyl rubber, it is cleavage.

Crosslinking Process

The rate of the volume change that accompanies the cooling of a high polymer becomes so slow at the second-order transition temperature that it introduces a discontinuity in the specific volume-temperature relation as it is ordinarily measured. Perhaps if a sufficiently long waiting period were allowed between changing the temperature and measuring the volume, the volume-temperature relation would be continuous to absolute zero.

Analogously, the rate of crosslinking may be diffusion controlled since hydrogen diffuses out of the polymer during crosslinking, and the molecular segments diffuse closer together—as is evidenced by hydrogen evolution and decreased specific volume (*3, 14*).

If it is postulated that crosslinking results when activated molecular segments diffuse together, then crosslinking is proportional both to the concentration of activated molecular segments and to the rate of diffusion. Suppose there exists an upper limit on the number of molecular segments that it is possible to activate. When the intensity of the radiation field is increased sufficiently that this upper limit is approached, the rate of crosslinking will become independent of intensity. Thus, the energy absorption approximation (*1*) can no longer hold. It appears that this condition will be approached at a lower intensity for the more rigid materials because the limiting value of the steady-state concentration of activated molecular segments will likely be approached at a lower intensity.* This suggestion is intended as a caution that, although the energy absorption approximation has been tested experimentally for nonrigid materials, it should not be assumed for very rigid materials without experimental confirmation. In the intensity

Definitions

"High elasticity" is confined to idealized elastomers in which the only mechanism for deformation is the uncoiling of molecular segments, and in which the restoring force results entirely from thermal motion of the molecular segments.

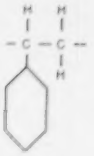
"Ordinary elasticity" is that involved with actual elastomers or plastics.

"Viscous flow" describes the liquid-like state that solids may assume under stress.

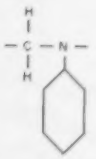
A = a constant of the order of 1 (*9*)
c = the rate constant
E = equilibrium value of Young's modulus for "high elasticity"
ΔE = increase in dynamic Young's modulus
ΔE_∞ = limiting increase for long exposure
k = Boltzman's constant
n = a parameter ≥ 1
R = exposure
T = absolute temperature
U = energy to produce a crosslink, electron volts
V = volume per crosslink
ΔV = decrease in specific volume
ΔV_∞ = limiting volume decrease that is approached at long exposure
y = deformation at time t after application of stress
y_0 = equilibrium value of deformation resulting from y
ρ = density
τ = retardation time; defined by: $y = y_0(1 - e^{-t/\tau})$
5.22×10^{22} = ev/rad

* Since the rate of deactivation by the crosslinking process is less.

FIG. 6. Polymer groups ranked in order of stability against cleavage



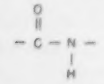
The repeating unit in the structural formula of polystyrene, which is the most stable of the unfilled polymers tested.



The repeating unit of aniline formaldehyde polymer. As for polystyrene, stability is attributed to the bulky benzene-ring-containing side groups.

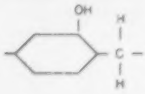
Present in many elastomers; since the stability of elastomers appears to be insensitive to the amount of unsaturation, this group is ranked with next group.

The repeating unit of polyethylene.

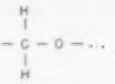


Present in Nylon, which shows the same order of stability as polyethylene.

The repeating unit of silicone rubber, which shows the same order of stability as most other elastomers.

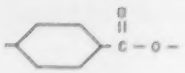


The repeating unit of phenol formaldehyde polymer. Presence of benzene ring in main chain is thought to increase cleavage, since unfilled phenolic crumbles for exposures that do not decrease strength of polyethylene (this contrasts with effect of benzene ring in polystyrene, in which it is in a side group).



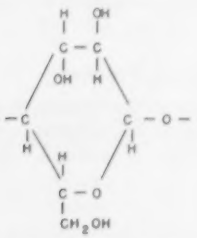
Also taken to be less stable than polyethylene. Polyallyl diglycol carbonate, polyvinyl formal, and polyvinyl butyral are softened. Selectron-5038 is hardened; however, this plastic is initially very soft and shows a high rate of crosslinking.

Present in Thiokol, for which a balancing of cleavage against crosslinking causes small hardness change, but decreases the ultimate strength.

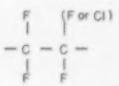


Present in Dacron. The predominant radiation change is embrittlement.

Present in polyvinyl chloride. Unplasticized polyvinyl chloride is softened by cleavage, though highly plasticized forms are hardened.



The repeating unit of cellulose. Rapid embrittlement of cellulosic plastics shows that this structure is sensitive to chain cleavage.



The repeating unit of Teflon and fluorothene, which become brittle and crumble apart at relatively short exposure. Resistance to cleavage is poor.

The repeating unit in polymers with quaternary carbon atoms: polymethyl methacrylate, butyl rubber, and polyalphamethyl styrene.

range 10^4–10^7 rad/hr, there was observed only small intensity dependence for many nonrigid materials. There also was observed no large difference in effects for polystyrene at 10^7 rad/hr and at a tenfold higher intensity. However, there was only small change for either irradiation.

The sensitivity of Young's modulus to crosslinking for ordinary elasticity has been explained in terms of increased retardation times. To explain the nearly constant rate of crosslinking (though the retardation times are increased), it is necessary to postulate that crosslinking does not microscopically restrict the diffusion of neighboring molecular segments except perhaps very close to crosslinking sites. The effect on the retardation times must then be largely caused by the formation of a network structure. Thus, it is possible for the macroscopic retardation times to be affected by crosslinking without affecting the microscopic diffusion rate of a large portion of the molecular segments.

From these considerations it appears necessary to restrict the correlation between rigidity, as measured by the Young's modulus, and the rate of crosslinking to noncrosslinked polymers. Even in the absence of crosslinking, the correlation is only an approximation since the microscopic rate of diffusion may be only roughly inferred by using Young's modulus to estimate the strength of the van der Waals forces.

The rate of crosslinking for certain of the nonrigid plastics and elastomers is nearly constant in the early stages of crosslinking, but later drops off rapidly. The decrease in specific volume may be fitted to the equation

$$\Delta V = \Delta V_\infty(1 - e^{-cR}) \approx \Delta V_\infty(cR), \quad \text{if } cR \ll 1 \qquad (2)$$

The dynamic Young's modulus was measured for several elastomer formulations (*13*). The increase in the dynamic Young's modulus at room tem-

perature and in the frequency range 10–100 cycles/sec is given by the empirical relation

$$\Delta E = \Delta E_\infty (1 - e^{-cR})^n \approx \Delta E_\infty (cR)^n, \quad \text{if } cR \ll 1 \quad (3)$$

Roughly the same value of c is given for Neoprene-GN either by the changes in the specific volume or the Young's modulus. For Hycar-OR, a higher value of c is found for Eq. 3 than for Eq. 2. Only for these two elastomers were sufficient data available to estimate c by both equations. Neoprene has a higher effective exposure owing to its chlorine content; Hycar-OR reaches a saturation value of Young's modulus quickly owing to a high value for n. The agreement in the case of Neoprene is taken as characteristic of elastomers with n less than 4; the lack of agreement of Hycar-OR is associated with the high value of n.

According to the kinetic theory of high elasticity, the Young's modulus should vary approximately in proportion to the concentration of crosslinks, although the situation is complicated by the "entanglement factor" (*15*). The experimental results indicate proportionality to the nth power of the concentration of crosslinks, where $n \geq 1$. Perhaps additional weight over that predicted by the kinetic theory is given to crosslinking, owing to increased retardation times. Disregarding the entanglement factor, the energy required to produce a crosslink may be calculated from (*13*)

$$U = 5.22 \times 10^{22} \rho AkT/(c^n \Delta E_\infty)^{1/n} \quad (4)$$

For the plasticized natural rubber formulations (*1*), Eq. 4 gives about 20 electron volts per crosslink, which is of the same order as given by swelling measurements for crepe rubber (*16*).

Cleavage Process

That crosslinking is the predominant radiation-induced process for many liquid hydrocarbons is evidenced by the viscosity change. Because of the similarity between elastomers and liquids, it is not surprising that many elastomers also are hardened by irradiation. As discussed, the rate of crosslinking is less for rigid materials. But, from Fig. 6, it is apparent that cleavage outweighs crosslinking for some materials.

Certain moderately rigid materials that have a low rate of crosslinking are also very resistant to cleavage. For example, polystyrene is among the most resistant of the polymers tested. Other materials of the same rigidity show much less resistance to cleavage. It appears that rigidity will not appreciably retard cleavage of moderately rigid materials. On the other hand, high resistance to cleavage is shown by extremely rigid, glassy polymers—triallyl cyanurate polymer and Araldite.

Figure 6 lists the chemical groupings of the polymers previously discussed (*1*) in order of stability against cleavage—excluding the very glassy polymers. The rankings in Fig. 6 are not precise with regard to some of the groupings that fall close together, but a very large difference in stability may exist between those spaced far apart. The manner in which the ranking was obtained is given in Fig. 6.

There is very little experimental data on the mechanism of cleavage in solid high polymers. For glassy polymers, the rate of cleavage is low and the radiation stability approaches that of the nonpolymeric materials (*17*). For the less rigid materials, the rate of cleavage is much greater. There is insufficient data for a very complete picture, but a simple concept is that atomic hydrogen, fluorine, and such, can react in some instances to break the main polymer chain.

The evolution of hydrogen gas indicates that atomic hydrogen is at some time present in irradiated solid high polymers. Similarly, the hydrogen halides are evolved by halogen-containing materials. If these atoms that are not part of the main chain are released, cleavage may occur as a possible consequence if they react with atoms in the polymer chains. Because of the high ranking in Fig. 6 for polyethylene, it appears that atomic hydrogen is not very effective in cleaving the carbon-carbon bond in the solid state; however, atomic chlorine may be more effective since the chlorine-containing materials rank lower. The low ranking of the ethers, the thioethers, and the quaternary carbon atom may indicate a high efficiency of atomic hydrogen in these cases. A rearrangement mechanism has been proposed that otherwise accounts for the low stability of the latter grouping (*18*).

Stress sensitivity of cleavage may explain differences observed in the radiation stability of different specimens of triallyl cyanurate polymer. This polymer is very glassy, and contains internal stresses resulting from shrinkage during polymerization.

Summary

Ordinary elasticity, high elasticity, and viscous flow are the mechanisms of deformation of solid polymers. Qualitatively, the effect of radiation on the mechanical properties of polymers can be described by considering the effect of crosslinking and cleavage on these mechanisms. Crosslinking tends to impede viscous flow. The equilibrium value of Young's modulus for high elasticity is directly proportional to the concentration of crosslinks, but for ordinary elasticity the sensitivity of the Young's modulus is less for the more rigid materials. Cleavage reduces the yield stress for viscous flow, and decreases the equilibrium value of Young's modulus for high elasticity. The Young's modulus for ordinary elasticity is again insensitive for the more rigid materials.

The changes in the mechanical properties of irradiated plastics and elastomers depend upon the rates of crosslinking and cleavage. These rates are governed both by the polymer's chemical structure and by the strength of the van der Waals forces. For uncrosslinked polymers, the change in Young's modulus is a measure of the crosslinking rate in the case of the less rigid materials. Sensitivity to chain cleavage has been correlated with chemical structure for the materials studied.

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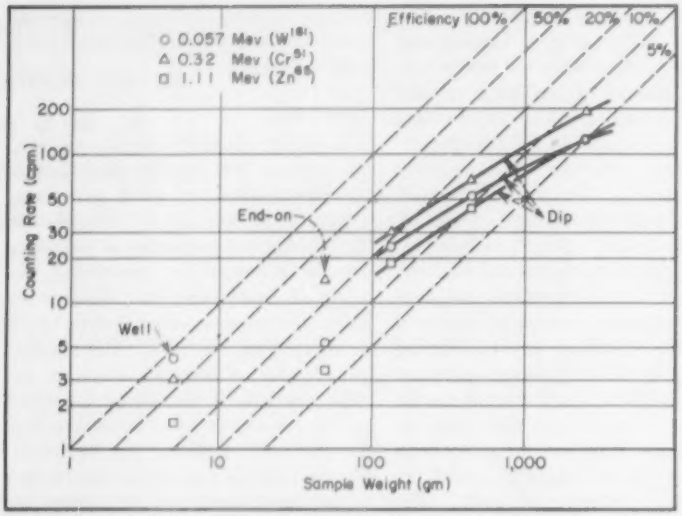


FIG. 1. Counting rates for solutions with 1 dpm/gm activity show higher counting rates and therefore lower usable specific activities for dip counter

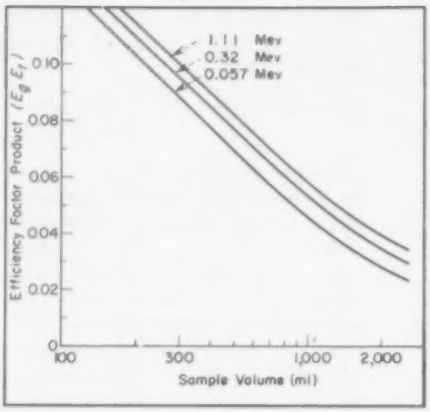


FIG. 2. Idealized model of a dip counter shows decrease in calculated product of geometrical and self-shielding efficiency factors with increase in sample volume. Dip counter was assumed as a spherical crystal surrounded by a spherical shell of sample solution

For Low Specific Activity: Use Scintillation Counting

Comparison shows that 10 dpm/gm of β-emitter is counted with 10% accuracy in 30 min, using liquid scintillator. Same accuracy results from 0.2 dpm/gm of γ-emitter, using scintillator dip counting. Latter corresponds to 1 mc mixed in 11,000 tons

By C. D. WAGNER and V. P. GUINN
Shell Development Company
Emeryville, California

ROUTINE METHODS for determining very low radioisotope concentrations are compared in this article, for the case of unlimited sample size. Basis of comparison is the concentration sensitivity—the minimum detectable specific activity—of the method. This sensitivity comparison is based on the specific activity needed for the same standard deviation for a given counting time. (See "Why Use Specific-Activity Comparison?" p. 57 for explanation of basis.) Methods for β- and γ-emitters are considered separately.

With detectors that record individual disintegrations in the sample, the number detected per minute, S, is given by

$$S = CW(E_g E_t E_a e) \qquad (1)$$

where C is specific activity in dpm/unit weight, W is sample weight, E_g is fractional solid angle subtended by the detector's active volume, E_t is the fraction of electrons or photons emitted within this angle that are not absorbed or scattered by the sample, and E_a is detection efficiency for particles and primary photons that enter the detector. The correction factor, e, includes back-scattering ($e > 1$), production of secondary photons that may be counted ($e > 1$), enhanced detection efficiency by crystal counters of these lower-energy scattered photons ($e > 1$), and absorption by material between sample and counter ($e < 1$).

To compare concentration sensitivity of various methods, the minimum value of C determinable within a reasonable time with a certain standard deviation can be used. Taking 30 min each as time for recording background and sample plus background, $\pm 10\%$ as the standard deviation, and assuming that statistics of random counts is the only factor limiting accuracy, the required sample counting rate, S_r, is

$$S_r = 5[1 + (1 + 2.4B)^{1/2}]/3 \qquad (2)$$

where B is the background cpm.

Combining this with Eq. 1 gives

TABLE 1—Comparison of Methods for Determining H^3 and C^{14}

Counting method	Minimum detectable specific activity [dpm/gm] (and sample weight [gm])					
	C^{14} as hydrocarbon	C^{14} as $BaCO_3$	C^{14} as CO_2	H^3 as hydrocarbon	H^3 as H_2O	H^3 as C_2H_6
Windowless flow*	1,480 (0.15)	16,200 (0.011)		63,500 (0.0035)		
Liquid scintillation†	7.6 (10)			64 (10)	2,580 (0.74)	
Internal gas‡			1,600 (0.019)			1,700 (0.018)
Ionization chamber¶			660 (0.28)			7,300 (0.13)

* Windowless counter (solid sample). The gas-flow type, windowless counter is assumed to have 20-cpm background, and to use a planchet and solid sample 5 cm^2 in area. Geometric efficiency, E_g, is assumed to be 0.50, and E_s is assumed 1.00. E_t from the infinite-thickness layer is considered since the maximum number of counts per minute is detected from a sample of at least this thickness. It is taken as 0.12. The correction factor, e, is assumed unity with hydrocarbon samples, but 1.25 for barium carbonate because of backscattering from the sample.

† Liquid scintillation counter (solid or liquid sample). For purposes of comparison we have used data obtained in our experience with a coincidence-type apparatus employing two channels and a 50-ml liquid scintillator volume. This apparatus was constructed in these laboratories, and patterned after that of Hayes (*5*) with modifications to adapt the instrument to routine analysis. The amplifiers and coincidence circuit were built for us by Tracerlab, Inc. C^{14} is determined with ~50% over-all efficiency ($E_gE_tE_se$) using a 10-gm hydrocarbon sample. H^3 is determined with ~6% efficiency using a 10-gm hydrocarbon sample, or with 2% efficiency using a 1-gm water sample obtained by hydrocarbon combustion. In the latter instance, 60 ml of ⅔ toluene-⅓ ethanol, by volume, containing 4 gm diphenyloxazole and 15 mg diphenylhexatriene per liter, is used to dissolve 1-ml water samples. Background is assumed to be 200 cpm.

‡ Internal gas counters (gaseous samples). The Bernstein-Ballentine counter (*4*) is assumed as representative of internal gas counters. C^{14} is measured as $C^{14}O_2$, obtained by hydrocarbon combustion. It is counted with ~90% over-all efficiency at 250-mm pressure (with admixed methane) in a 100-ml tube with a background of 100 cpm. For H^3, the water of combustion is converted to ethane by using zinc diethyl or ethyl magnesium bromide, and the ethane-H^3 then counted at ~90% efficiency in the same tube at 500-mm pressure.

¶ Ionization chamber (gaseous samples). The same gaseous compounds, carbon dioxide and ethane, are used as fillings for the ionization chamber at atmospheric pressure. A 500-ml ion chamber is used, with 90 volts polarizing potential, and with the ion current detected by the rate-of-charge method, using a vibrating-reed electrometer. Experience in these laboratories has shown that a current of 5×10^{-14} amp may be measured in 30 min to ±10% when superimposed upon backgrounds of 5×10^{-14} and 7×10^{-14} amp for carbon dioxide and ethane respectively, at atmospheric pressure. This current, 5×10^{-13} amp, has been found to correspond to 185 and 950 dpm for C^{14} and H^3, in the 500-ml volume at 750-mm pressure. For this purpose, Eq. 3 is replaced by a more appropriate one, $C_r = (I_r A/I)/W$, where I_r is the ion current due to the sample that is just determinable to ±10% in 30 min, A/I is dpm for a given isotope per unit of ion current (determined by calibration), and W is weight of hydrocarbon from which the chamber filling is derived.

$$C_r = \frac{5[1 + (1 + 2.4B)^{1/2}]}{3WE_gE_tE_se} \qquad (3)$$

where C_r represents the limiting specific activity determinable.

Methods for β-Emitters

Counting methods for γ-emitters are more concentration sensitive than those for β-emitters, so that methods for β-detection should ordinarily be applied only to isotopes that emit β-rays only, or emit γ-photons in only a small fraction of disintegrations. In the petroleum industry the more important pure β-emitters are H^3 and C^{14}. Several widely applied methods were analyzed for their concentration sensitivity for H^3 and C^{14}. Sample is assumed to be a nonvolatile hydrocarbon, analyzing 85% C and 15% H. In cases where the sample is counted in a chemical form other than the original hydrocarbon, W represents the weight of sample hydrocarbon required by stoichiometry to give the amount of material counted.

Concentration sensitivity of four methods—windowless gas flow counter for solids, liquid scintillation counter (*1*) for solid or liquid, internal gas counter for gases, and ionization chamber for gases—are compared in Table 1.

Basic difficulty in attaining concentration sensitivity with all of these methods, except the liquid scintillation method, is the small effective sample size. In the windowless counter this is due to sample self-absorption, since WE_t reaches a maximum at "infinite thickness." In the gaseous methods, an increase in sample size requires either a larger counter, with significantly higher background, or operation under pressure, which also involves a higher background and is less convenient. The sensitivity advantage of the liquid scintillation counter arises from the sample being in a condensed, homogeneous phase in the active volume, so that self absorption is no problem and sample weight can be large. Ten grams is not the maximum that can be used, but is a convenient amount.

For C^{14}, liquid scintillation counting is much preferred. Where the sample is highly colored or quenches the fluorescence* the sensivitity may be reduced. If this is very serious, the sample could be burned and the CO_2 measured in an ion-chamber, or by other methods. Liquid scintillation counting has another very important advan-

* With colored samples, or those which partly quench the fluorescence, an efficiency correction must be made by addition of a small known amount of the isotope being counted, and re-counting.

Why Use Specific Activity Comparison?

Tracer applications in the petroleum industry (5) frequently involve dilution of tracer by as much as thousands of barrels or hundreds of tons. Isotope measurement therefore often involves very low isotopic concentrations in samples of any size. This requirement of concentration sensitivity without sample size limits contrasts with biological applications where sample size is generally limited and methods must have high absolute sensitivity.

Since hundreds of samples must be analyzed in some applications, the methods should be relatively simple. Procedures involving evaporations, distillations, and precipitations are at a distinct disadvantage.

TABLE 2—Minimum Determinable Specific Activity of Isotopic Solutions

Counting arrangement	*Required gamma photons/minute/gram of*		
	0.057 Mev	*0.32 Mev*	*1.11 Mev*
Crystal well (5-gm sample)	9.1	12.6	23.3
End-on (50-gm sample)	7.1	2.65	10.7
Dip			
135 gm	1.60	1.25	2.10
450 gm	0.72	0.55	0.89
2,500 gm	0.30	0.20	0.31

tage: with liquid and solid samples sample preparation simply involves dissolving the sample in the liquid.

For H^3, the liquid scintillation method is also very much preferred. If the sample cannot be counted directly, it may be burned to water, and the water directly analyzed by the same method. While the internal gas counter is twice as sensitive as this analysis for H^3 in water, the difference is hardly worth the water-to-ethane conversion.

The cost of large-scale application of C^{14} and H^3 to petroleum problems is low. One hundred dollars worth of C^{14} (2.8 mc) may be diluted in one million liters of liquid, and one hundred dollars worth of H^3 (1 c) may be diluted in 43 million liters of liquid, and their concentrations still be determined to ±10% in 30 min. by liquid scintillation counting.

Methods for γ-Emitters

Because of the low absorption coefficients for γ-rays, and exponential absorption, the concentration sensitivity for γ-photons is not necessarily limited by a maximum value of WE_i as is the case with β-emitters. The problem with γ-detection has been the low absorption efficiency of gas-filled G-M counters and ionization chambers (~1%). In contrast, E_a for NaI crystals of moderate size, and for usual γ-ray energies, ranges from 0.30–1.00. High concentration sensitivity for γ-emitters comes from using crystal scintillation counters.

There are three ways of using a crystal counter: 1, put the sample inside the crystal (well counter); 2, put the crystal at the center of the sample (dip counter); and 3, put the sample next to the crystal (end-on method). These methods have been compared experimentally, using W^{181} (0.057-Mev γ), Cr^{51} (0.32 Mev), and Zn^{65} (1.11 Mev).

Apparatus. The crystal-well counter is a 1¾-in.-diameter × 2-in.-high canned Harshaw well-type crystal with a ¾-in.-diameter × 1½-in.-deep hole, used with a 2-in. DuMont 6292 photomultiplier. This assembly, with dynode and single-tube cathode follower circuits, is housed in a lead shield with 7 cm of lead surrounding the counter and 6 cm of lead above the crystal. Cellulose acetate vials that fit the can hole are used to hold the samples. A 5-ml sample fills the vial to the level of the crystal top.

The dip counter is a 1¾-in.-diameter × 2-in. canned Harshaw crystal, used with a 2-in. DuMont 6292 photomultiplier. These components with their circuitry are housed in an aluminum cylinder. The crystal is surrounded by a snugly fitting 0.030-in. aluminum nose-piece. The dip counter was used for the end-on counter also.

Procedure. About 3-liter solutions of each isotope were prepared with added carrier, in strengths to give observed counting rates of well-counter samples of the order of several thousand per min. All counts were taken for a period long enough to record more than 10,000 counts/determination. Appropriate coincidence corrections were made for the higher counting rates. For the 26-day Cr^{51}, appropriate decay corrections were made; they were not necessary with the other isotopes.

† W^{181} decays by *K*-electron capture, emitting only X-radiation, with the 57-kev *K* X-rays being predominantly detected. Cr^{51} also decays by *K*-capture, emitting 0.32-Mev γ-radiation in about 5% of the disintegrations; its X-radiation is not detected with the counter employed. Aside from the low-energy X-rays (not detected) emitted by Zn^{65}, 3% of the disintegrations produce annihilation radiation and 46% produce 1.11-Mev γ-rays. The correction for the contribution of the 0.51-Mev annihilation radiation to the Zn^{65} counting rates for the well, end-on, and dip counter has been computed as 12%, 12%, and 14%, respectively. The Zn^{65} values given are corrected values.

The other arrangements were tested by putting a 50-ml sample in a 50-ml volumetric flask and counting with the flask mounted on the flat crystal end of the dip counter (end-on counting) or by inverting the counter and placing it with the crystal at solution center in a beaker (dip counting).

Standardization of solutions. Because the decay schemes of two of the isotopes are somewhat involved,† an indirect method based on photon detection alone was used to determine the specific γ-activities. Counting rate in the crystal-well counter (5-gm sample) is given by $S = 5CE_gE_tE_a\epsilon$. With the well counter these efficiency factors may be found, and C thus determined.

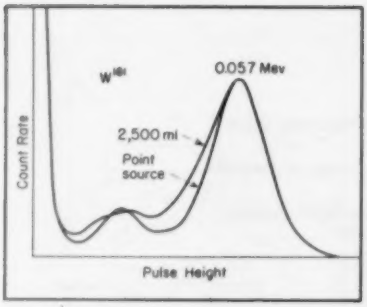
Values of $E_t\epsilon$ for the isotopes used were determined by comparing the counting rate from a 5-ml aqueous solution with that from the same amount of activity without the water absorber. The ratio of the counting rate from the solution to the rate from the anhydrous sample is $E_t\epsilon$, because E_g was held constant in the counting arrangement. Values of 0.967, 1.028, and 1.022 were found for $E_t\epsilon$, W^{181}, Cr^{51}, and Zn^{65}, respectively. The effect of the $\frac{1}{32}$-in. aluminum case on these values is believed negligible.

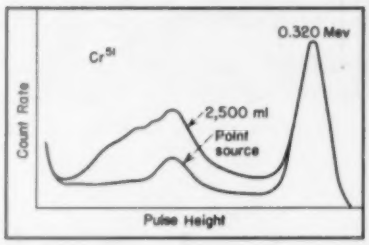
E_g was calculated as 0.87, by simple integration of the solid angle subtended by the crystal from the source solution. This value was verified experimentally, using W^{181}.

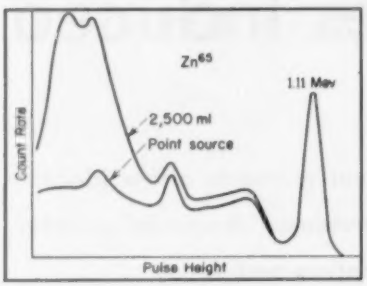
E_a can be calculated if the effective crystal thickness is known. This is somewhat greater than the actual thickness, because the γ-rays strike the crystal at virtually all possible angles. To determine this effective thickness, a calibrated solution of Fe^{59} was used.‡ Half of the Fe^{59} γ-rays are 1.1 Mev and half are 1.3 Mev. The β-energy is low enough (< 0.5 Mev) so that they are absorbed completely by the case. By using values of 0.87 for E_g, and 1.020 for $E_t\epsilon$, E_a was determined experimentally to be 0.330. For sodium iodide, μ for 1.1-Mev γ-rays is 0.204 cm^{-1}, and for 1.3-Mev γ-rays μ is 0.185 cm^{-1} (*2*). With 0.194 as the average value, the effective thickness, d, in $E_a = 1 - e^{-\mu d}$ is 2.06 cm. Actual thickness is 1.27 cm.

From this effective thickness, and the respective total-absorption coefficients in sodium iodide for γ-photons of 0.057, 0.32, and 1.11 Mev (27.7,

‡ Obtained from Tracerlab, Inc.







FIGS. 3–5. Gamma-ray spectra for point and dissolved sources of radioisotopes

0.565, and 0.202 cm^{-1}), the respective values of E_a are 1.000, 0.68, and 0.34. Values of $E_g E_a E_t \epsilon$, the combined efficiency factor for γ-photons, are then 0.842, 0.616, and 0.304, respectively. Using these values for the absolute efficiency of the well counting arrangement, all the observed counting rates were then converted to those corresponding to unit specific activity—1 γ-ray photon/min/gm—as shown in Fig. 1 for the three arrangements.

Concentration Sensitivity

In comparing methods for concentration sensitivity, Eq. 3 applies. Values of $WE_g E_a E_t \epsilon$ used to plot Fig. 1 may be used directly. Observed backgrounds (shielded by 2 in. of lead) are 200 cpm for the counters. Calculated values of C_r are given in Table 2. The concentration of γ-emitters may be determined in solutions as low in specific activity as 0.2 γ-photons/min/gm. This level is about 40 times lower than that attainable with the best β-counting method.

The limiting specific activity for a 2,500-ml sample, 0.2 γ-rays/min/ml, corresponds to 1 mc dispersed in 10,000 metric tons of material. This is about ⅕ the volumetric γ-ray specific activity caused by K^{40} in the human body.

The arrangements are affected differently by the efficiency factors. With the well counter E_g and $E_t \epsilon$ are close to unity, but the relatively short crystal path leaves the sensitivity controlled strongly by E_a, which is very sensitive to the γ-energy. The other arrangements use a much thicker crystal. In these instances E_g is relatively small (0.05–0.5) and predominates in determining sensitivity. Differences among the isotopes are caused by self-absorption in a sample (affecting W^{181}, 0.057 Mev, particularly) and by different detection efficiencies (affecting Zn^{65}, 1.11 Mev, particularly). Photons of about 0.3 Mev are detected with greater efficiency than either of the other energies studied, principally because neither of these factors is as serious at this energy.

Refinements in these methods are possible. Larger samples may be used for dip counting, with a sensitivity increase. But sensitivity does not increase as rapidly with samples larger than 2,500 gm, because of self-absorption and decreasing geometrical efficiency. Shielding problems increase significantly. Using a larger crystal would have several advantages: (*a*) E_a would increase, particularly with higher-energy γ-rays, (*b*) E_g would increase, and (*c*) E_t would increase because of the smaller sample thickness. These effects would improve concentration sensitivity in spite of the concomitant increase in background.

Dip-Counting Efficiency

Dip-counting results will now be compared with values computed from a simplified theoretical model. The model assumes that the crystal is a sphere (2.65-cm radius) with volume equal to that of the cylindrical crystal, and that the sample constitutes 9/10 of a spherical shell with internal radius 3 cm and external radius b. The other tenth is taken up by the scintillation counter itself. The number of primary γ-photons emitted from a spherical shell of the aqueous sample that intersect the crystal is given approximately by $dS = 0.9 C_r \pi R^2 e^{-\mu(r-3)} dr$ where C_r is specific activity/ml, μ is linear absorption coefficient (narrow-beam attenuation coefficient) for water, R is crystal radius, r is distance from shell to detector center, and dr is shell thickness. Integrating over the sample, and dividing by the total γ-photons emitted, gives the efficiency-factor product

$$E_g E_t = \frac{3R^2(1 - e^{-\mu(b-3)})}{4\mu(b^3 - 27)}$$

Sample weight, assuming unit density, is $0.9(4/3)\pi(b^3 - 27) = 3.78(b^3 - 27)$. Calculated values of $E_g E_t$ have been plotted against W in Fig. 2.

Assuming the effective crystal thickness is ~4.5 cm, E_a is calculated as 1.000 for W^{181}, 0.92 for Cr^{51}, and 0.60 for Zn^{65}. Using these values and the computed $E_g E_t$ values, the expected product $E_g E_t E_a$ is found to be somewhat smaller than the observed values of $E_g E_t E_a \epsilon$ (points in Fig. 1 referred to the efficiency coordinates). The ratio of observed/theoretical ranges from 1.35 to 2.25 for samples of 100–1,000 grams, depending also upon the γ-ray energy. Part of this discrepancy is caused by inadequacy of the theoretical model, and part is caused by the quantity ϵ. Factors that contribute to a value of ϵ greater than unity are (*a*) contribution of secondary Compton γ-photons produced in the thicker samples, and (*b*) greater detection efficiency of the crystal for these lower-energy secondary photons. Figures 3–5 show dip-counter γ-ray spectra¶ for a point source of isotope vs those for 2,500 ml of isotope solution. The increased contribution by lower-energy scattered photons is clearly evident.

* * *

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¶ These were obtained with a single-channel pulse-height analyzer, Atomic Instrument Co. model 510, modified by the incorporation of a motor-driven sweep for the baseline, with output pulses fed into a Tracerlab Superscaler ratemeter insert, and recorded on a Brown Electronik recording potentiometer.

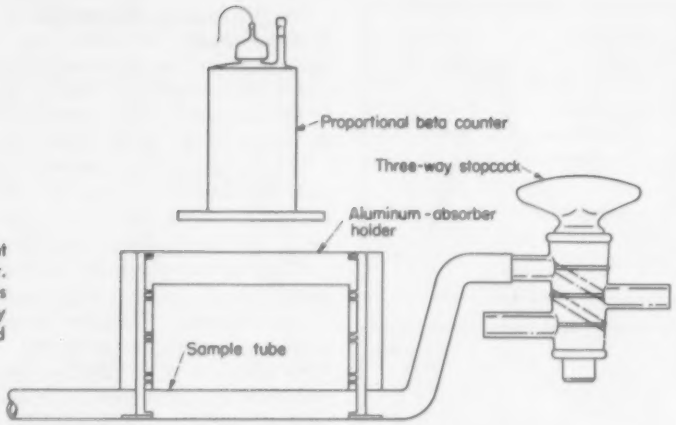

FIG. 1. Counter assembly for measurement of nitrogen-16 in reactor cooling water. Water admitted through stopcock flows through sample tube. Counting assembly is shielded from stopcock by 3 in. of lead brick

Radioactive Species Induced

Gamma spectrometry, decay studies, and chemical methods allow identification and measurement of reactor-induced activities. A special counter, fed cooling water from the core, measures absorption and decay

TABLE 1—Impurities in Cooling Water as Determined by Spectrographic Analysis

Element	*Approximate concentration (ppm)**
Ag	<1
Al	<1
Be	0.05
Ca	4
Cr	5
Cu	10
Fe	20
Mg	0.3
Mn	<1
Na	<100
Ni	<4
Si	2
Ti	3
Zn	<30
Zr	<1.5

* < indicates limit of detection. Actual concentrations may be much lower than stated limits.

WHAT RADIOACTIVE SPECIES are induced in demineralized cooling water when it passes through the high neutron flux inside a reactor? This article describes three different types of radiochemical determinations that were made, and their results.

Table 1 lists the impurities that were found in the circulating water by spectrochemical analysis. This sample was obtained at the same outlet and in the same manner as those used for radiochemical analysis. The water had been circulated in the reactor system for a period of time sufficiently long to "saturate" activities as long-lived as 15 hours. The maximum flux to which the water was exposed was $\sim 4 \times 10^{13}$ n/cm²/sec. The water came in contact with aluminum, stainless steel, cast iron, and carbon steel.

Short-Lived Activity

The only activity of half-life greater than a few seconds and less than one minute was N^{16}, produced by the reaction $O^{16}(n,p)N^{16}$. How N^{16} in the water was identified and its concentration estimated are described in this section.

Since N^{16} has a quite short half-life, it was decided to make energy measurements on a steady-state system containing the activity. Beta-absorption data were chosen for the activity measurement since N^{16} has two extremely hard beta rays: 4 and 10 Mev (*1*).

The experimental assembly used to measure the N^{16} in the water is shown schematically in Fig. 1. A three-way stopcock was attached to the outlet line from the water system. Water entering the stopcock could then be sent either through the counter assembly or directly to the drain.

The counter assembly consisted of an argon-methane-filled proportional beta counter connected through a scaler to a linear counting-rate meter and a fast-response recorder. A stand-

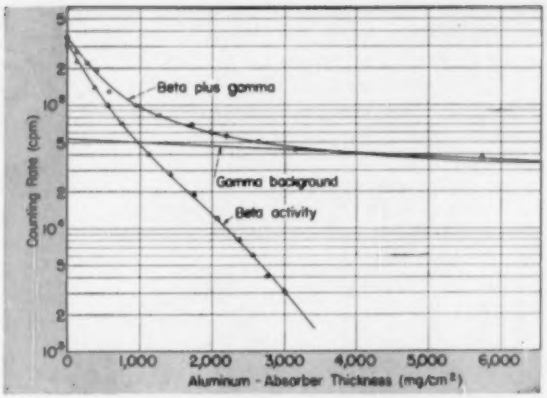

FIG. 2. Aluminum absorption data for reactor cooling water

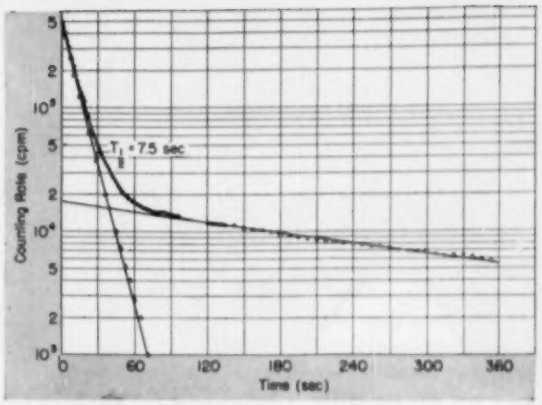

FIG. 3. Short-lived decay of reactor cooling water

in Reactor Cooling Water

By W. S. LYON and S. A. REYNOLDS
Analytical Chemistry Division
*Oak Ridge National Laboratory**
Oak Ridge, Tennessee

ard aluminum sample-card holder was placed between the counter tube and the sample tube through which the active water passed. The sample tube was made of aluminum tubing about 1 cm in diameter with wall thickness of about 1 mm everywhere except directly below the tube window; here the aluminum wall was filed down to about 0.4 mm thickness for about 1 cm along the length of the tubing.

The entire assembly of counter, shelf and sample tube was held in place on a table by clamps and screws and was surrounded on all sides by lead brick.

The experimental procedure was to allow cooling water to flow through the tube for several minutes until a steady-state activity had been reached. Absorption data were then obtained by placing aluminum absorbers below the counter tube and observing the decrease in counting rate. Data were taken on water from an outlet from the reactor, whose intake was located near the fuel lattice.

Figure 2 is an absorption curve that was obtained. The components of the composite beta and gamma curve were resolved by subtracting out the hard gamma background contributed by the 6- and 7-Mev gamma rays associated with N^{16}. The beta activity is due to the 10- and 4-Mev beta rays of N^{16}.

The counter was calibrated by clearing the sample tube of water and filling it (through the third arm of the stopcock) with a solution of radioactive Ru^{106}-Rh^{106} (3.5-Mev beta ray) of known concentration, and obtaining aluminum absorption data. The efficiency of the counter tube was obtained by dividing the observed counting rate of the known Ru-Rh solution by the true disintegration rate (dpm/ml) of the standard solution. The activity of the water was found by dividing the

TABLE 2—Gamma Emitters Induced in Cooling Water

Nuclide	*E (Mev)*	*Half-life*	*10^5 dpm/ml*
Na^{24}	1.38	15.1 hr	1.3
	2.75	15.1 hr	1.3
Mg^{27}	0.84 (58%)	9.5 min	1.4
	1.01 (42%)	9.5 min	1.4
Al^{28}	1.78	2.3 min	6

TABLE 3—Radioactivities Induced in Cooling Water

Activity	*Half-life*	*dpm/ml*
N^{16}	7.3 sec	1.8×10^5
Al^{28}	2.3 min	6×10^5
Mg^{27}	9.5 min	1.4×10^5
Na^{24}	15.1 hr	1.2×10^{5}*
Cu^{64}	12.8 hr	2.7×10^4
Mn^{56}	2.6 hr	2×10^4
Ag^{110}	270 day	2.8×10^3

* Average of results by gamma spectrometry and radiochemical analysis.

* Operated for AEC by Union Carbide Nuclear Company.

observed counting rate of the water by the tube efficiency.

Decay data were obtained in the water to ascertain what activities were being detected by the counter. These data were obtained by closing the stopcock so that no more water entered the tube and following the decay of the water in the sample tube. Figure 3 indicates the short-lived decay of the water. It shows the presence of N^{16}, together with a longer-lived background.

The activity observed from the absorption data then had to be corrected to the time of leaving the reactor. This time was found by opening the stopcock and measuring the time required for the active water to reach the counter. This time was observed to be 18 seconds, and using this figure and the half-life for N^{16} (7.3 seconds), the observed data were corrected. The activity found was calculated to be 1.8×10^5 dpm/ml.

Intermediate Gamma Emitters

It was of interest to find what gamma-emitting nuclides with half-lives greater than one minute and less than one day were present in the water. For the identification of electromagnetic radiation, a NaI(Tl) gamma-ray spectrometer is most useful (*2*).

For these experiments, such a spectrometer was kindly loaned by F. C. Maienschein, Oak Ridge National Laboratory. The counter consisted of a 3×3 in. cylindrical NaI crystal with a well about $1\frac{1}{2} \times \frac{3}{4}$ in. This well-type crystal was cemented to a DuMont 3-in. photomultiplier. Pulses from the photomultiplier were fed through an A-1-A preamplifier, an A-1 amplifier, and then to a 40-channel differential pulse analyzer. The counting rate in each channel was recorded on a mechanical register.

Data were obtained from 300 kev to 4.3 Mev with each channel width 100 kev, and again from 150 kev to 2.15 Mev with 50-kev channel width.

A hollow cylindrical aluminum shield ($\sim$1.3 gm/cm^2) was placed in the crystal opening to absorb most of the beta radiation from the sample. Samples of water were obtained, were made to 2 ml in volumetric flasks, and then placed within the crystal. The decay of the gamma spectrum of the water was followed on the multichannel analyzer.

Figure 4 shows the decay data obtained with analyzer set for the range

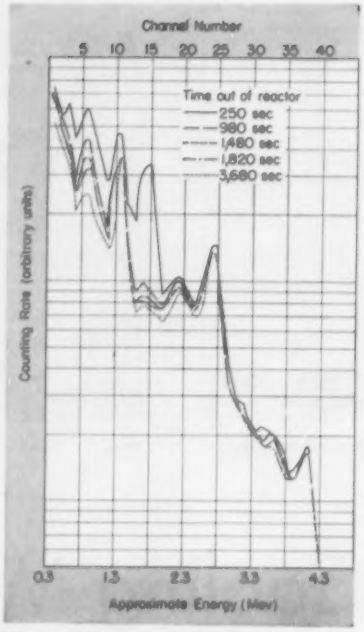

FIG. 4. Decay of gamma-ray spectrum (0.3–4.3 Mev) of reactor cooling water

300 kev to 4.3 Mev. Similar data were taken for the range 150 kev to 2.15 Mev. From the data of Fig. 4, it was concluded that there was no gamma radiation of energy greater than the 2.8-Mev gamma ray from Na^{24}. The peak at 4.1 Mev is a "pile-up" peak caused by coincidence summing of the Na^{24} 2.8-Mev and 1.3-Mev gamma rays. Decreasing the geometry of the counter by moving the sample away from the crystal removed this peak; in addition, known samples of Na^{24} gave a peak with the ratio of 2.8- and 4.1-Mev gamma rays identical to that of the water sample.

The areas beneath the observed photopeaks were obtained by graphical integration, and the decay of each peak was plotted.

An energy and efficiency calibration of the counter was made by measuring aliquots of known disintegration rate of Na^{24} (1.37-Mev and 2.75-Mev gamma energy) and Cs^{137} (0.661-Mev gamma energy) in the scintillation-counter assembly in a manner similar to that used for the samples. The area beneath the photopeak obtained from the gamma spectrum of each nuclide, when divided by the true disintegration rate, gave the efficiency of the counter for that energy gamma. These true points were used to construct an efficiency-vs-energy curve from which efficiencies for the various observed energy photopeaks were obtained.

The area beneath the photopeaks, when divided by the appropriate efficiency, yielded the absolute emission rate of each gamma ray. From the energy, intensity and decay data (*1*), the radioactivities listed in Table 2 were identified. The values given in the last column of Table 2 are absolute disintegration rates of the nuclides. These are identical with the emission rate of the gamma rays with the exception of Mg^{27}, which has relative gamma intensities as in the second column (*3*).

The Na^{24} is formed by the reactions $Al^{27}(n,\alpha)Na^{24}$, $Na^{23}(n,\gamma)Na^{24}$, and $Mg^{24}(n,p)Na^{24}$. Mg^{27} is formed by $Mg^{26}(n,\gamma)Mg^{27}$ and perhaps a small amount by $Al^{27}(n,p)Mg^{27}$. Al^{28} is formed by $Al^{27}(n,\gamma)Al^{28}$.

Longer-Lived Activities

The radioactive contaminants remaining in cooling water after several hours decay were determined by radiochemical analysis. Analyses for Mn, Cu, Na, and Ag activities were performed under supervision of G. W. Leddicotte by methods in use by the ORNL Analytical Chemistry Division (*4*).

Summary

The presence of a number of induced radioactivities in reactor cooling water has been quantitatively established. Table 3 is a summary of the data obtained. It is believed that the results reported herein could not be used to anticipate *quantities* of the same activities produced in another reactor. However, this information may be of use in indicating the radioactive species to be expected. A more complete account of this work has been published elsewhere (*5*).

If a leak occurs in a reactor fuel element, fission-product and Np^{239} activities would be expected to be present in the water. These may be determined by standard methods (*6*).

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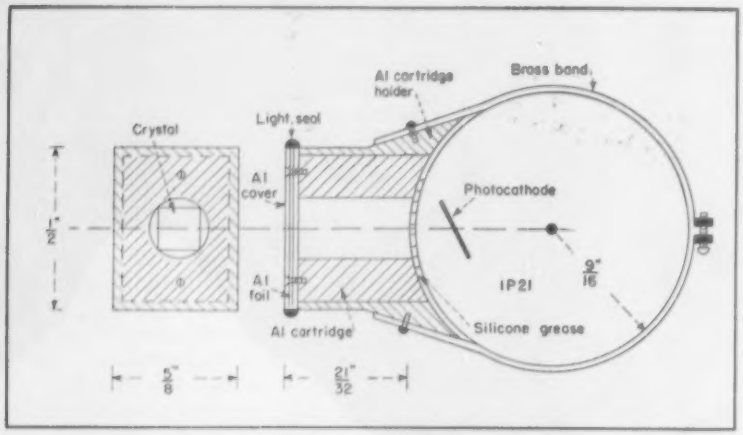

FIG. 1. Scintillation-crystal mounting (longitudinal and cross sections)

Localizing Scintillation Counting-Rate Meter

By HERBERT JONAS
Cancer Research Laboratory
University of Virginia Medical School
Charlottesville, Virginia

In a study of K^{42} uptake by plants (*1*), it was necessary to study *in vivo* the radioactivity in small areas of leaves without physiologically disturbing them. A detector utilizing a scintillation crystal, similar to detectors used in brain surgery for localizing P^{32} (*2*), has proved satisfactory.

Detector

A rectangular anthracene crystal (*3–5*), with a cross section of 3.5 × 4.0 mm, is fitted in an aluminum holder, which is fastened to the horizontally positioned window of a 1P21 photomultiplier tube (*6, 7*), as shown in Fig. 1. The crystal is cut 15.0 mm long to stop most K^{42} beta particles and some of its gamma rays. One end of the crystal is cut and polished to the curvature of the photomultiplier glass envelope; a thin layer of high-vacuum (silicone) grease provides good optical coupling between the tube and crystal. An aluminum-foil reflector around the sides of the crystal improve scintillation efficiency and light conduction. The end of the crystal facing the source is covered with a 12.7-micron aluminum foil held in place by a covering frame.

The crystal and photomultiplier are placed in an aluminum can containing a cathode-follower preamplifier and power and signal-cable connections. Around the outside of the can is wound a coil of copper tubing through which cooling water flows. Tap water at about 10° C reduces the background count owing to photomultiplier thermal noise to 100 cpm. Apiezon-Q sealing compound and electrician's tape stop light leaks to the photomultiplier.

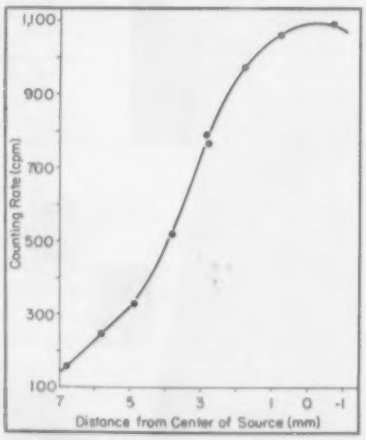

FIG. 2. Counting rate as function of distance between centers of UX_2^{234} source and anthracene crystal

Counting Circuit

The pulses from the detector-head preamplifier feed into a linear amplifier and then into a counting-rate meter (General Radio Co. Type 1,500A), which is modified for improved sensitivity control. The ratemeter output drives a recording milliammeter.

An optimum 900-volt d-c potential for the photomultiplier is selected because it is centered in the linear portion of the plot of the apparent activity of the reference uranium source as a function of d-c potential. Linear-amplifier gain is adjusted so that it is located at the inflection point of a plot of gain versus the logarithm of the background activity at 12.5° C. At this temperature, the amplification of photonoise becomes noticeable. The sensitivity of the ratemeter is chosen so that a 0.15-volt signal just becomes audible.

Localization Efficiency

Figure 2 describes the degree of localization obtained with the detector when a UX_2^{234} source, which emits 95% 2.32-Mev beta particles and 5% 0.80-Mev gamma rays (*8*), was moved parallel to the detector window. The source was 4.5 × 4.0 mm; source-detector vertical clearance was 1.6 mm.

The apparatus efficiency (4.6%) was approximated by comparing the counts of a 40-mg-$K^{42}HCO_3$ sample in a 5-ml Pyrex test tube, 1.6 mm below the scintillation detector head, with the activity of the same sample as determined by an ionization chamber of almost 100% geometry (*9, 10*).

Application

Sunflower plants placed in K^{42}-tagged potassium bicarbonate solution were mounted so that one leaf of the fourth pair was in loose contact with the crystal cover (1½ mm from crystal to epidermis). The crystal was centered above the central vascular strand of the leaf, 2 cm from the petiole. The leaf was mounted on thick blotting paper covering a ¼-in. lead plate to shield against stray radiation from K^{42} in the lower plant organs. The bicarbonate solution was shielded by lead plates and bricks. Each plant was

kept in the solution for 2–3 days while the activity was recorded.

* * *

This work was undertaken while the author was a Postdoctoral Fellow of the National Research Council.

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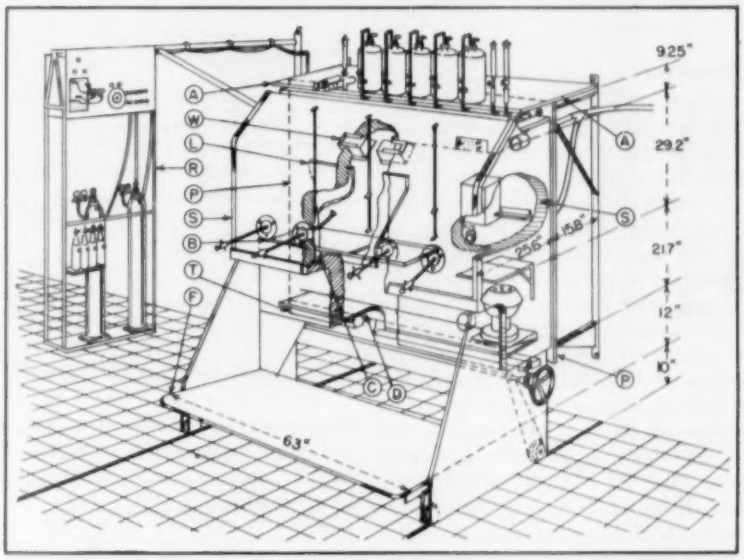

SHIELDED BOX consists of three main parts: wooden back panel (*P*) and shelf (*A*) above it, both firmly attached to wall of room; movable shield (*S*) with platform (*F*) for operator, mechanical manipulators, and window (*W*); rack (*R*) with gas tubes and electrical controls

Shielded Box for Chemical Work

By JAN RYDBERG
Research Institute of National Defense Sundbyberg, Sweden

While cells for multicurie work are very expensive to build, most laboratory budgets permit work at the curie level. This paper describes a box built to handle samples of the order of 1 curie. The cost ($4,000) should not exceed by much that of a lead-shielded dry box; flexibility equals that of a Brookhaven hot cell.

The shield (see illustration) can be moved back on rails so as to permit free access to the panel. All equipment for a certain experiment is either mounted on the panel (e.g., the centrifuge) or placed on the stainless-steel trays (*B*), which are removable and rest on angle bars mounted to the panel. All electrical connections and tubes for gases and liquids also pass through the panel.

On the back side of the panel, which is about 1½ ft from the wall, a small interchange box is placed. Since this box is situated about 1½ ft from the right side of the shield, different objects can be introduced into the large box, without exposing more than the operator's arm to the radiation. This irradiation can, of course, be avoided, if the operator uses tongs, though this is usually not necessary.

When the shield is in place against the back panel, foam-rubber strips provide an airtight seal. The air, which is always under reduced pressure inside the box, enters and leaves the box through gas-mask filters. The box can be filled with an inert atmosphere.

The shielding round the box consists of a 10-cm thickness of iron, supplemented in the front by 3-cm thickness of lead (*L*). The lead-glass window (*W*) in the viewing hole is 11 cm thick. The shielding efficiency of these materials is sufficient to permit continuous work with 1-curie, 0.7-Mev gamma-ray sources. There is no shielding on the back side (no persons work on the other side of the wall) and very little on the top. The radiation scattered through the unshielded parts of the box can be neglected at the 1-curie level. At higher radiation levels, additional shielding is necessary, and 10–15-cm-thick lead blocks can then be piled up on the inside shelves (*C* and *D*) of the shield. There is also sufficient space for increasing the thickness of the lead-glass window. However, at radiation intensities much above 1 curie, the scattered radiation becomes important, and the top and back side must then be covered by appropriate shielding. The present shield weighs 4 tons.

The mechanical manipulators and the view through the lead-glass window cover the whole space inside the box (except for the lowest part at the height of the centrifuge motor; in this space, waste bottles, etc, are kept). Electric current and gas flow is controlled on the rack (*R*), which can be swung over close to the side of the box. The shelf (*A*) above the box is easily reached, which permits controlling liquid flow into the box and pumping and suction action of the syringes.

When contaminated, the box can be completely washed inside. The wash liquid drains through a valve (not shown) in shelf *D* into a trough (*T*), which is attached to the back panel below the box. When the shielding is removed, any liquid that remains on shelf *D* drains into this trough. All liquid waste from the box finally drains into a shielded bottle (not shown) at some distance from the box.

One of the main advantages of this design is that a procedure can be tested in its final arrangement with the shield moved away from the panel so as not to hinder the tests. In this way, preliminary trial runs can be made using the hands so that all *chemical* operations can be tested more easily and rapidly than by using manipulators. However, a true dummy run should of course be carried out with the shielding covering the equipment.

* * *

The author wishes to thank the head of the Chemistry Department, Prof. G Ljunggren, for encouraging this work.

Inhibitor Breakdown in Zinc-Bromide Shielding Windows

By DANIEL T. HAWORTH*
Marquette University
Milwaukee, Wisconsin

To prevent radiation-induced breakdown and coloration of zinc bromide in shielding windows, hydroxylamine hydrochloride is added to the liquid shield (*1*). The change in the zinc bromide occurs and is inhibited by the reactions

$$HBr + (\text{radiation}) \rightarrow H_2 + Br_2$$
$$2H_2NOH + 2Br_2 \rightarrow H_2O + N_2O + 4HBr$$

Upon exhaustion of the inhibitor, the free bromine formed will cause a yellow coloration of the liquid. Due to the expense and time involved in replenishing the inhibitor, the dose for breakdown has been determined for various concentrations of the inhibitor.

Experiments

Using the "yellowness factor" as defined previously (*2*)

$$\text{Yellowness} = \frac{\%T_{6,500\text{Å}} - \%T_{4,500\text{Å}} \times 100}{\%T_{5,500\text{Å}}}$$

various concentrations of inhibitor in zinc bromide were irradiated using a Co^{60} source of 375,000 r/hr at ½ in. The factor was measured with a Beckmann D.U. spectrophotometer under the following conditions: slit width was 0.09, 0.07, and 0.24 for 4,500 Å, 5,500 Å, and 6,500 Å, respectively; sensitivity setting, 1.0; standard, air; silica cells, 1.0-cm light path.

The following concentrations were prepared using Eastman Kodak hydroxylamine hydrochloride and Dow Chemical zinc bromide, which contained 0.01% inhibitor as originally obtained from the manufacturer: 0.01%, 0.1%, 0.75%, 1.00% and 10.00%. The concentration of the $ZnBr_2$ was 77.0% with 2.50 density.

The absorption spectrum of zinc bromide was observed before and after breakdown (Fig. 1). An absorption maximum was observed at 3,900 Å (slit width = 0.16) after breakdown.

A typical plot of yellowness vs. dose is shown in Fig. 2. The breakdown dose was taken at the point of sharp increase in the yellowness factor.

The breakdown dose also was determined by observing the decrease in transmission of the zinc bromide at 3,900 A (Fig. 3 and the table). After breakdown the transmission decreased rapidly due to the formation of bromine.

From Fig. 4, the following equation was derived: breakdown dose = 3×10^7 (% inhibitor)$^{0.38}$.

Discussion

W. B. Doe suggests that 4 oz of hydroxylamine per 100 gal of zinc bromine will protect a small volume from 10^6 r of incident radiation (*2*). If a 3-ft-thick window is used, the zinc bromide can withstand 10^6–10^7 r, assuming that the dose is extended over a period of time to allow for thermal mixing (*3*). Since 4 oz of inhibitor corresponds to a 0.022% (wt) solution of inhibitor, a 1-cm thickness could be protected from 7.0×10^6 r, and if a 3-ft-thick window is used, maximum protection to 64×10^7 r can be obtained. This is in good agreement with Doe (*3*). The 4 oz/100 gal is actually 0.012%; however, 0.01% inhibitor is added by the manufacturer.

The most satisfactory amount of inhibitor would depend on the level of radiation to be used. However, the most economical amount of inhibitor would be in the range of 3.8–4.5 oz of hydroxylamine per 100 gal of zinc bromide.

Care should be taken never to allow the yellowness to exceed 10, or to allow the transmission at 3,900 Å to fall below 75%. Should this occur, quantitatively determine the inhibitor.

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Decrease in Transmission of $ZnBr_2$

Inhibitor conc. (%)	*Breakdown dose (10^6 rep)*	
	By yellowness factor	*By %T at 3,900 Å*
0.01	5.3	5.5
0.10	13.0	12.5
0.50	21.0	22.0
0.75	27.0	27.7
1.00	30.0	30.0
10.00	72.0	72.0

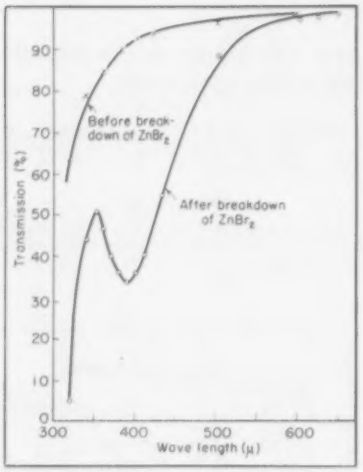

FIG. 1. Absorption spectra of ZnBr

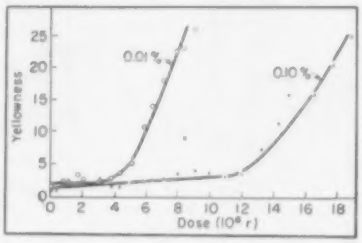

FIG. 2. Typical radiation yellowing

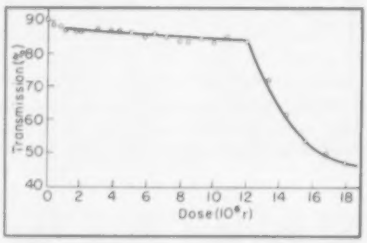

FIG. 3. How radiation decreases transmission of zinc bromide at 3,900 Å with 0.1% inhibitor

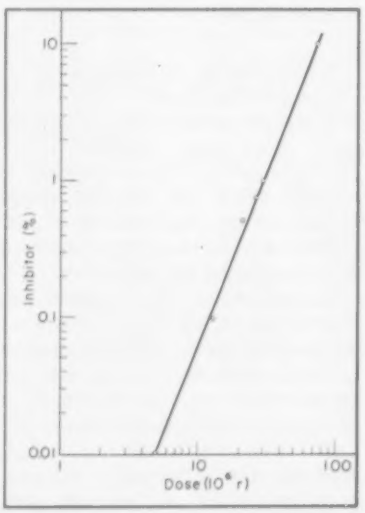

FIG. 4. Effect of inhibitor on breakdown

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General Motors Builds Radioisotope Laboratory

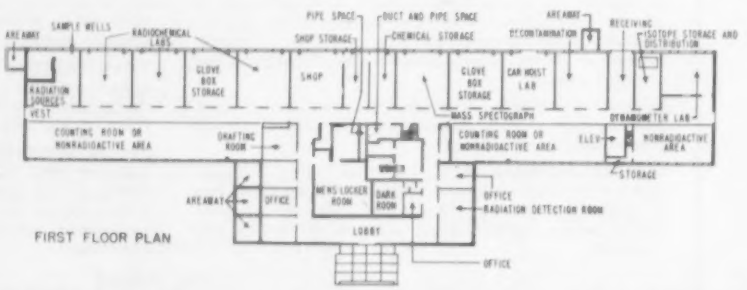
By A. SOMERVILLE
Research Laboratories Division
General Motors Corporation
Detroit, Michigan

A radioisotope laboratory, where industrial and research applications of radioisotopes will be explored, was completed in July at the GM Technical Center in suburban Detroit.

The facilities are available to all GM technical personnel. The permanent laboratory staff provides men trained to handle radioisotope problems.

Most of the basic research units are Berkeley-type glove boxes, which can be shielded with up to 6 in. of lead. Since the boxes are on roller tables, unused units can be sent to the decontamination and storage areas.

Most radioactive waste is handled in carboys attached to each glove box. The rest of the waste water passes through a separate drain system, is collected in storage tanks, assayed for radioactivity, and finally pumped into the sanitary sewer system.



RESEARCH PROGRAM keeps handling of large quantities of unsealed material at ends of building wings; contamination gradients are maintained in wings with glove-box storage rooms as buffer zones. Aluminum roof sections minimize backscatter in source and source-preparation rooms. Pit surrounded by 3-ft-thick concrete serves for bulk-isotope storage; two small storage wells in each laboratory and counting room extend 3 ft below basement floor. One-pass, nonrecirculating, 2-duct hot-and-cold air system is used; minimum 10 air changes/hr is provided in radioisotope laboratories and 5/hr in other rooms; air supplied to wings is exhausted through radioactive work rooms; differential pressure is automatically maintained; boxes are individually exhausted; standby fans and power assure continuous building and box exhaust. Basement houses building utilities

Launching view of the Seawolf, America's second nuclear-powered submarine, for which Combustion built the reactor vessel and other components of the nuclear power system.

Combustion Engineering, *Builder of Nuclear Components for Seawolf,* becomes Third Major AEC Contractor to enter Naval Reactor Development Program

On August 11, the Atomic Energy Commission announced the award of a contract to Combustion Engineering for the design, manufacture, assembly and test of a submarine nuclear power reactor and its related equipment. Only two companies had previously been awarded such contracts—the Westinghouse Electric Corporation and General Electric Company.

Combustion brings to this important assignment the experience already gained in building the reactor vessel and other related components for both the Seawolf and its prototype in the sphere at West Milton, N. Y., which recently became the first nuclear source of commercially distributed electricity for public use. This experience is further augmented by design, research and development work in the field of atomic power over the past eight years, including the manufacture of the reactor vessel, presently in process, for the AEC-Duquesne Light plant —the country's first commercial-size nuclear power station.

In executing its AEC submarine contract, Combustion will utilize new manufacturing facilities now being erected at its Chattanooga plant, plus additional facilities to be established in a new Nuclear Engineering and Development Center scheduled for completion in 1956. *Thus Combustion Engineering will become the first company in the country to provide its own facilities for the construction of a naval nuclear reactor.*

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Operating a Hurst-Type Fast-Neutron Dosimeter in High Gamma Fields

By J. T. BRACKEN,* E. A. ROLLOR,* and J. A. MOHRBACHER
Convair Division
of the General Dynamics Corp.
Fort Worth Division
Fort Worth, Texas

For accurate measurements with a fast-neutron dosimeter (*1–4*) in a nuclear-reactor radiation field, gamma interactions must be discriminated against or compensated for (*5, 6*).

The detectors used in our study were a commercial version (Radiation Products, Inc., Detroit) of the Hurst fast-neutron dosimeter (*7*), which was designed to satisfy the Gray cavity principle (*8*). Although our system uses pulse amplification and amplitude discrimination against gammas, the pulse-height distribution of the dosimeter output is altered by three gamma effects: (1) gamma pile-up, (2) neutron-gamma coincidence, and (3) shielding of the central-wire region by heavy-ion space charge (*9, 10*).

With proper over-all gain and discriminator setting, gamma pile-up can be avoided. However, neutron-gamma coincidence results in a forward shift of the pulse-height distribution along the energy axis, thus increasing the dose indication above that for fast neutrons alone. The space charge alters the electric field about the detector's central wire and thus lowers the gas amplification; intense background radiation also decreases the gas amplification of proportional counters (*11, 12*). We find that the last two effects can be compensated for by selecting a combination of anode voltage and over-all gain such that the space charge and coincidence effects cancel each other.

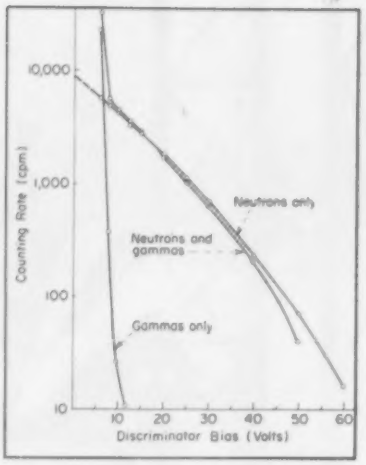

FIG. 1. Effect of 7-r/hr gamma field on integral bias curve for Po-Be neutron source

Experimental Apparatus

The detector consists of a cylindrical brass case partitioned to form two coaxial chambers approximately 4.3 cm in diameter and 3.2 cm long, with a common central wire 0.5 mil in diameter. The chambers are lined with polyethylene sheet $\frac{1}{16}$ in. thick, which serves as the recoil-nucleus radiator. This liner is sprayed with a thin coat of aqua dag to obtain a conducting surface for the outer electrode, and the counter is filled to two atmospheres with methane.

The associated electronic equipment is arranged in a conventional manner. A Fluke Company high-voltage supply model 400B supplies the detector anode potential, and the voltage is measured at the preamplifier with an electrostatic voltmeter. The amplification system consists of a preamplifier and linear amplifier† (*3*), the output of which feeds into a pulse-height-integrator circuit (*14*). The output of the amplifier discriminator feeds into a decade scaler, and the amplifier discriminator is adjusted so that the slope of the input-pulse height vs discriminator-dial curve is unity and the intercept is zero.

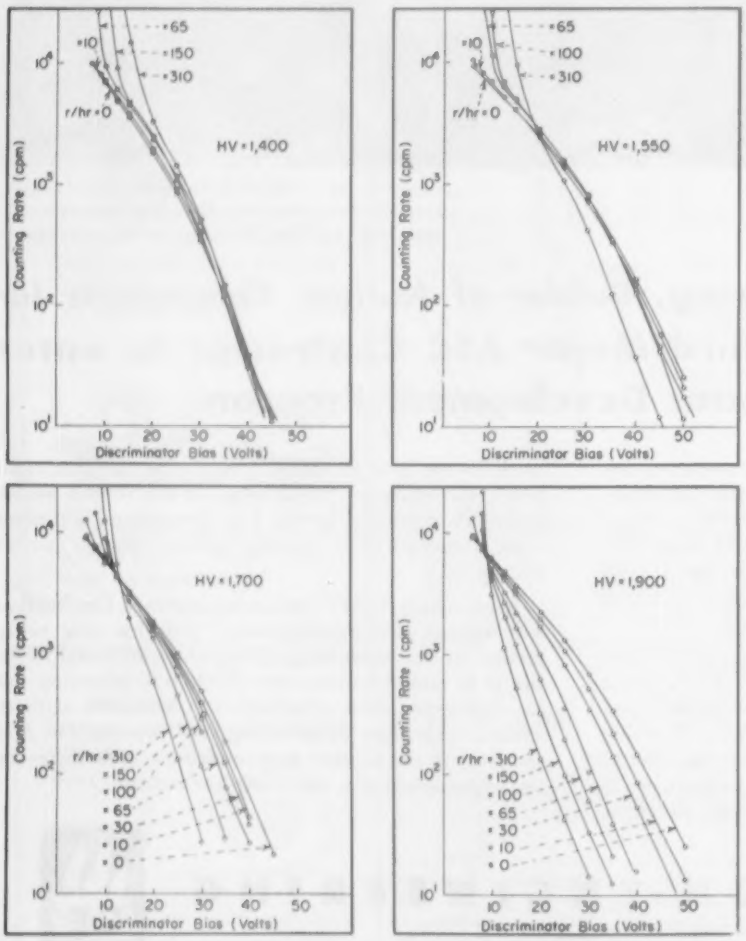

FIG. 2. Effect of gamma fields of 0, 10, 65, 150, and 310 r/hr on neutron integral bias curve at anode potentials of 1,400–1,900 volts

* Present Address: Military Operations Research Engineering Div., Lockheed Aircraft Corp., Marietta, Ga.

† Atomic Instrument Co. model 204B; 0.5 Mc bandwidth, risetime = 0.8 μsec, decay time = 5 μsec.

Two Co^{60} gamma sources, 1 and 70 curies, were used. The dosage from the 1-curie source was measured at several separation distances with a Victoreen Instrument Company condenser r-meter. In measurements involving the 70-curie source, the various intensities were calculated by the inverse-square law. Po-Be neutron sources were used to supply the neutron flux.

Discussion of Data

The change in a neutron-produced integral bias curve as a result of operation in a 7-r/hr gamma field is shown in Fig. 1. Comparison of the neutrons-only and neutron-and-gamma curves shows that the effects of space charge and neutron-gamma coincidence on the pulse height are equal at a pulse height of approximately 17 volts. The space charge is predominant at higher pulse heights and neutron-gamma coincidence at lower values. In the neutrons-only curve, the sharp increase below 8

Space-Charge Problem

Ordinarily, space charge in a proportional counter is negligible. Only in the limited-proportional and G-M regions is the gas amplification factor large enough to produce a sufficient number of positive ions to modify the electric field significantly. However, if the primary ionization is great, then the space-charge effect occurs in proportional counters operated at low amplification.

The number of positive ions formed within the ionization radius (distance from the counter axis at which field is sufficient to permit electrons to acquire enough energy between collisions for secondary ionization) is n(A-1), *where* n *is the number of electrons reaching the ionization radius and* A *is the amplification factor. Because of the slow drift velocity of the heavy ions, a positive-ion space-charge equilibrium can exist if the time rate of primary events is sufficiently great. Positive-ion space charge reduces the electric field strength in the vicinity of the central wire and therefore reduces the ionization radius and the gas amplification.*

Negative-ion space charge can occur by electron attachment if electronegative gases are present. The result is a decrease in the ionization radius, an increase in the electric field strength close to the central wire, and thus a decrease in the amplification factor.

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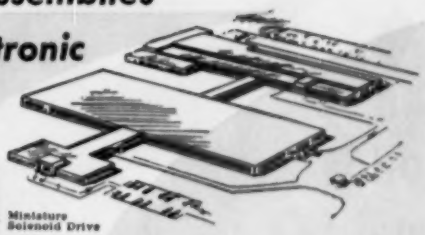

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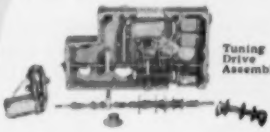
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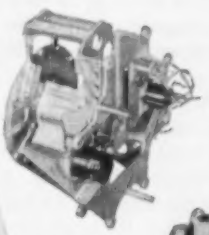
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volts is the result of gamma pile-up. Curves similar to those of Fig. 1 have been obtained when the counter gas was continuously flowed. Flowing minimizes the possibility of the presence of electronegative gases as a result of contamination of the counter walls, etc., at the time of filling.

Figure 2 illustrates the behavior of integral-bias curves for Po-Be neutrons in gamma fields of 0-310 r/hr and with anode potentials of 1,400–1,900 volts. At 1,400 volts, it appears the neutron-gamma coincidence is predominant over the space charge effect, except in the region of the large pulses. In the 1,900-volt case, all of the gamma-distorted curves lie below the neutron curve over the entire region of interest (>10 volts), indicating a marked predominance of space charge. The 310-r/hr curve indicates a reduction in pulse height of about 40% for a 50-volt initial pulse height.

If these curves are chosen to be representative of the typical counter, then gamma pile-up is of no consequence for operation in fields up to about 30 r/hr. However, each of the other two processes has a considerable effect on the area under the integral-bias curve, which, as mentioned previously, is the quantity measured by the integrator. It will be noticed that these two effects are opposing, and the resultant effect is thus smaller than either of its components. This suggests a possible choice of high voltage to optimize the cancellation.

Figure 3 shows the effect of a 100-r/hr gamma field on pulse height for a high voltage of 1,550 volts. This information was inferred from Fig. 2 (1,550-volt anode potential) by reading the pulse-height values from the zero and 100-r/hr integral-bias curves for several values of counting rate. The straight line with nonzero intercept indicates the macroscopic effects are:

1. Addition of a constant pulse-height increment (equal to the intercept) due to neutron-gamma coincidence.

2. Reduction of the gas amplification by a multiplying factor (equal to the slope of the line). This may be expressed analytically as

$$P_\gamma(P_0,R,A_0) = \frac{A_\gamma(R,A_0)}{A_0(V)}\,[P_0 + P_c(R)^*]$$

where P_0 is the initial pulse height ($R = 0$), $P_c(R)^*$ is the mean coincidence addition (equal to the horisontal intercept) and is a function of the gamma field R, and P_γ is the modified pulse height. $A_0(V)$ is the initial gas amplification factor as a function of anode voltage, and $A_\gamma(R,A_0)$ is the actual gas amplification of the detector in the gamma field.

In Fig. 4, all points correspond to the same over-all gain in zero gamma field. The over-all gain can be determined on a relative basis as the ratio of the integrator count to the number of pulses that trigger the lowest discriminator.* This number is one-fourth the height of the average pulse accepted by the integrator circuit. The accuracy of the measurements is highly dependent on the ability to reproduce the same over-all gain at each high voltage. The high voltage at which the curve crosses the voltage axis is the best operating voltage for a gamma field of 11.3 r/hr. The slope of the curve is small in this region and decreases as the gamma field is reduced. Therefore, even though the critical voltage might shift for

* A lower discriminator setting of 10 volts was used instead of the usual 6-volt level. The same weighting factor of 4 volts per count was maintained by adjusting the 6-volt discriminator so that it would trigger at 10 volts.

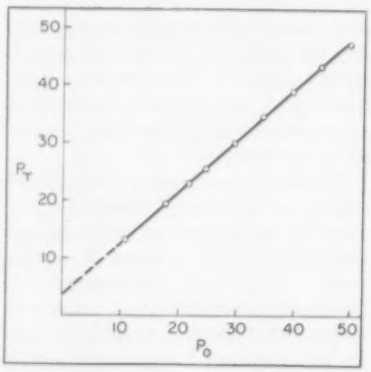

FIG. 3. Effect of 100-r/hr gamma field on pulse height for 1,550-volt high voltage; P_0 = pulse height for zero gamma field, P_γ = pulse height modified by 100-r/hr gamma field

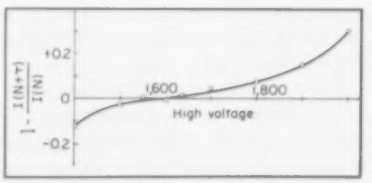

FIG. 4. Fractional change in integrator counting rate for Po-Be neutrons in gamma field of 11.3 r/hr as function of anode voltage

smaller r/hr values, it is doubtful that an error of ±1% in integrator count would be exceeded by using this voltage in all gamma fields up to 11.3 r/hr.

It should be pointed out that the choice of the 11.3 r/hr was arbitrary, and the possibility of operation in higher fields is not excluded. One detector, operated at the optimum high voltage for 11.3 r/hr, has been used in a gamma field of 20 r/hr without observable gamma effects.

Conclusion

The static fast-neutron dosimeter can be operated in high gamma fields by selecting a combination of anode voltage and over-all gain such that the space charge and coincidence effects cancel each other. Positive space charge can be reduced by increasing the diameter of the central wire. If, however, the space charge in these counters is principally negative, it can be reduced by improved counter construction and filling procedures. In either event, the neutron-gamma coincidence will be present and the aforementioned compensation cannot be accomplished if the space charge is appreciably reduced.

If the data were sufficiently accurate over the entire range of values to permit an isolation of the two effects by the method of Fig. 3, then the analytical relationship between gas amplification, high voltage, and gamma fields could be determined and compared with the results of previous work (*12*). This is not the case, however, and the data as such precludes any quantitative correlation between these variables.

* * *

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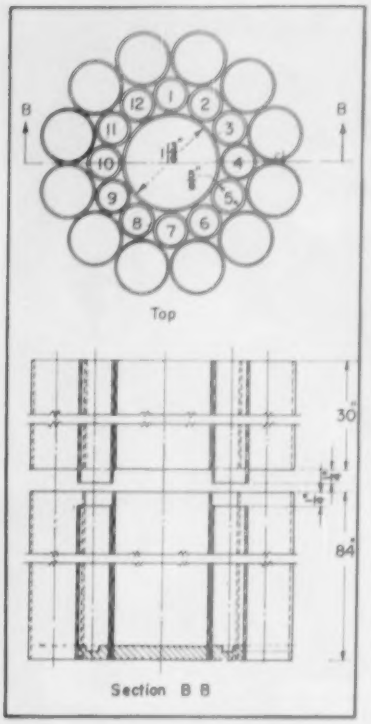

FIG. 1. Center tubes 1, 4, 7, and 10 contain Co^{60} capsules in this earth-shielded source. Steel pipe about 6-in. diameter lines the 7-ft deep hole. Bottom of hole is sealed with waterproofed concrete. Top tube bundle is just long enough to reach from lower bundle to desk top. Bottoms of all tubes are closed with hard-soldered brass plugs

FIG. 2. Top of bottom tubes is 2 in. above floor. Concrete platform 30-in. o.d. × 3½-in. thick surrounds tubes. Plate 24-in. diameter, with a 7-in. central hole, is attached to concrete. Upper battery of tubes is contained in 6-in. i.d. steel pipe

Design of an Inexpensive High-Intensity Gamma Source

By MILTON BURTON,* J. A. GHORMLEY,† and C. J. HOCHANADEL†

All the larger Co^{60} sources intended for work in radiation chemistry (*1–8*) are characterized by the number of curies not being readily changeable and by high cost of Co installation. Great size is accompanied by great weight. Usually the more flexible the uses of the device, the heavier and more complicated is the construction. Relatively simple devices may be built at relatively low cost but have limited flexibility either for modification or for use. For the type using a lead shield, the cost for a 300-c source is in the range $8,000–$10,000.

Advantages of New Design

Design of this Co^{60} source is based on several years of experience with an underwater source (*9*). It is difficult to estimate its cost because many of the elements were developed by trial. An instrument company interested in possible marketing of the device estimated a sales price of $950 without cobalt. We estimate that the cost, if home-made, should not exceed $500 for machine work‡ and materials. Co^{60} is currently listed at $5/c plus other charges (*10*).

Special advantages of this new source are: (*a*) Source is designed so a standard shipping container and delivery unit can be used for the Co^{60}. This container, a rather costly device, is owned by the Isotopes Branch of Oak Ridge National Laboratory. In a typical shipment, container return from Notre Dame to ORNL cost $90.41. (*b*) Source provides several radiation intensities (on different levels) that differ by fixed ratios. In the Notre Dame prototype the top level has $\frac{1}{100}$ the bottom-level intensity. (*c*) Radiation intensity on any one or all three levels can be changed at any time by buying more Co^{60}. If a cheaper radioisotope becomes available, it can be encapsulated, shipped, handled and inserted in the source as desired. Neither of these features is characteristic of other present sources. (*d*) In addition to the principal exposure chamber there are a total of up to 20 different chambers that can be used. In each chamber there are three different radiation-intensity levels. (*e*) Temperature controls are easily introduced either in the source or around the samples. For example, samples can be irradiated in Dewar vessels, or in small furnaces. (*f*) Tubes or electrical leads connected to external apparatus are easily introduced with the sample. (*g*) Samples are very readily exposed for a precisely known time at a calibrated intensity. (*h*) Source assembly is easily and safely loaded with radioisotope capsules. The latter are moved from shipping container to source assembly with a minimum of hazard, even by relatively inexperienced personnel. (*i*) Sample exposures are virtually without hazard. But certain precautions must be maintained when making fundamental changes in operational features of the source, *e.g.*, when increasing the amount of Co^{60} on any level.

Source Construction

The source was designed not merely for simplicity in operation and construction but also with an eye to availability of materials within the required tolerances. Essentially (Fig. 1) it consists of a bundle of "telescopic" brass tubes—tubes drawn to nominal wall thickness of $\frac{1}{32}$ in., with difference in successive o.d.'s of $\frac{1}{16}$ in. An upper bundle provides access for samples and sources. The central exposure chamber is $1\frac{13}{16}$ in. o.d. It is surrounded by 12 tubes of $\frac{5}{8}$ in. o.d., which are in turn surrounded by 12 tubes of 1 in. o.d.

For convenience this source is best located in a basement laboratory. The source assembly itself is inserted in a 7-ft-deep hole in the ground and extends about 2 in. above floor level. It is keyed to the upper battery at tubes 4, 7, and 10 by a ¼-in. overlength of the upper tubes and a corresponding shortening of the three lower tubes. Figure 2 is a photograph of the source ready for operation. Normally it is covered with the brass cover that has a central hole large enough for free access to the central exposure hole.

* Department of Chemistry, University of Notre Dame, Notre Dame, Indiana.

† Chemistry Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

‡ For the machine work the following equipment was used: band saw, 16- and 10-in. lathes, vertical milling machine, and drill press.

Soft-soldering the tubing to form a battery is the most difficult part of construction. After this, the lower tube battery is put in the hole in the ground. The tubes are fixed into vertical position and centered in the hole. To protect against scattered radiation the vacant region around the tubes may be packed with sand or lead wool. We used much of the latter. All the tubes are temporarily stoppered with rubber stoppers, and fine shot (obtainable from W. M. Welch Mfg. Co.) or sand is poured into the empty prisms. Location lines (extending to the outer edge) are now marked on the aluminum cover of the concrete base surrounding the top of the hole. These lines accurately fix the center point of each of the 5/8-in. tubes in relation to the center of the exposure hole. Careful marking is necessary for proper introduction of Co ampoules. Brass rods are used to plug unused tubes (and also the Co tubes after Co has been added). The lower parts of the Co holes are loaded with 3-in.-long keyed and slotted brass rods. This elevates the lowest cobalt capsules. This arrangement is required by the fact that the sample carrier (Fig. 3) necessarily has 7 in. of lead at its bottom.

Assembling the source is now complete and it is ready for loading. Loading is performed directly from the ORNL shipping container without any possibility of personnel exposure. The container is spotted over the hole with a block and tackle. Guide marks on the container are aligned with the location lines on the aluminum cover plate. A temporary lead-brick barrier is built. The safety screw is removed from the Co capsule, and a long rod threaded on. Discharge hole in the carrier is then aligned with the container hole, and the Co capsule pushed down into the source tube, and its key engaged in the slot in the previously inserted brass spacer.

The other levels of Co capsules are loaded in the same manner, after turning the shipping container so another capsule aligns with the source tube. The upper tube battery is then put in place. Radiation level above the central hole is only 80 mr/hr with no shielding. Actually the lead at the bottom and top of the sample carrier effectively cut out any radiation.

The sample carrier itself is attached to a stainless-steel rod and the rod attached to an airplane cable that extends over two pulleys to a counterweight. On the steel rod are several

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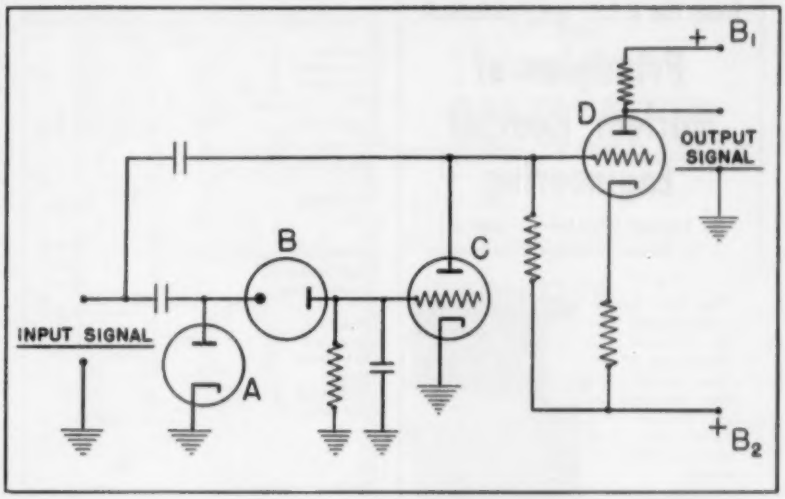

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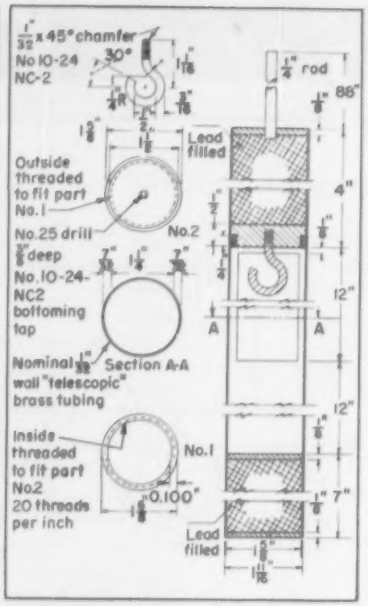

FIG. 3. Sample carrier is lead shielded at top and bottom. Sample length should be less than 4 in. (length of active Co capsule). For good calibration, sample length should be reduced to 2 in. Upper part of carrier is threaded to fit lower part at 88

numbered aluminum collars (made from ½-in. stock). They are arranged in pairs and held by Allen screws so that they can be moved to any desired position on the rod. One stop on the steel rod or cable is fixed so that it interrupts the upward movement as it passes over the first pulley, thus preventing the lead plug at the bottom of the sample holder (see Fig. 3) from rising above the top of the hole. A slotted brass plate inserted between a pair of plugs stops the descent when the plate reaches the top of the central hole (at the desk top) and thus fixes the sample holder and the sample at a predetermined position. In addition, a slotted lead shield about 2-in thick × 5-in. diameter may be placed over the central hole for added safety.

Source Characteristics

Intensity within the Notre Dame source was determined in July 1954 as a function of height from the bottom, using a 10-ml ferrous-sulfate dosimeter (*9, 11*). Values assumed were: 100-ev yield, G (Fe^{++} to Fe^{+++}) = 15.8 and ergs/gm r = 93. Figure 4 shows the plot of r/min for the lower two levels. The source is supposed to contain about 125 c of Co^{60} on all levels. The maximum value on the lowest level, about 66,000 r/hr, is to be compared with 47,800 r/hr in a 120-c cylindrical source described by Schwarz and Allen (*8*). The third or highest level has not been calibrated; in this prototype unit, its intensity was set at about $\frac{1}{100}$ that of the bottom level. So far no experiments have been planned requiring such a low level. Since calibration at a low-intensity level is rather tedious, it will be deferred until needed.

In ordinary use radiation levels at vulnerable points close to the source (feet, seat height, and source top) are less than 0.2 mr/hr. Thus, the operator could not possibly get the maximum permissible dose of 300 mr/wk.

This prototype unit is safe, flexible in use and modification, convenient to operate, apparently devoid of characteristics that make for trouble, and relatively inexpensive. It is recommended to institutions that want to get into research in the field of radiation chemistry (*12*) in a scientifically sound and desirable way but at minimum cost.

* * *

A more extensive version of this paper, containing more details on fabrication technique, may be obtained on application to any of the authors.

The authors express their appreciation to Mr. John Jaroszewski and Mr. H. L. Weisbecker for contributions to the design of

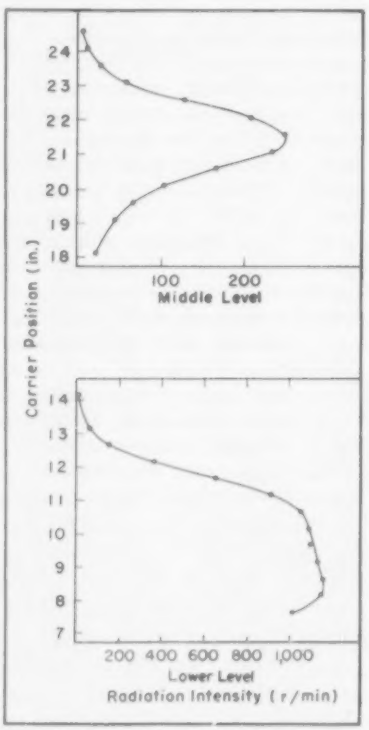

FIG. 4. Calibration curve shows height above hole bottom vs radiation level

the source and to Dr. H. A. Dewhurst, Mr. Paul Berry, and Mr. Peter Phung for calibrations and determinations of intensity levels.

This article is a joint contribution from the Radiation Project of the University of Notre Dame, supported in part under U. S. Atomic Energy Commission contract AT(11-1)-38 and Navy equipment loan contract Nonr-06900, and from the Oak Ridge National Laboratory, whose work is performed for the Atomic Energy Commission.

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TECHNICAL BRIEFS

Electronic instrument counts, sizes aerosols. A new instrument can size particles from 1 to 64 microns in diameter into 12 groups at rates up to 100 per sec. Size measurement is based on the light scattered by the particles onto a photomultiplier; the output pulse height varies as the square of the particle size and is some 650 μsec in duration. Pulses from the photomultiplier are analyzed in a pulse-height analyzer to give the particle-size distribution. The development of the Aerosoloscope was a joint endeavor of the Armour Research Foundation and the Chemical Corps Biological Laboratories.

In-pile cryostat permits low-temperature irradiation. A helium refrigerator circulating cold helium gas through a cryostat in vertical hole 12 of the ORNL graphite reactor will permit irradiations at 20° K with a 300-watt capacity. The aluminum cryostat has a 1¼-in.-diameter sample chamber. The usable length inside the heat exchanger, which will be in the center of the reactor, is 18 in. The total length of the cryostat is 22 ft; the lower 15 ft is made entirely of 28 aluminum.

A helium refrigerator with a rated capacity of 120 watts of heat load was acquired and modified for its present capacity.

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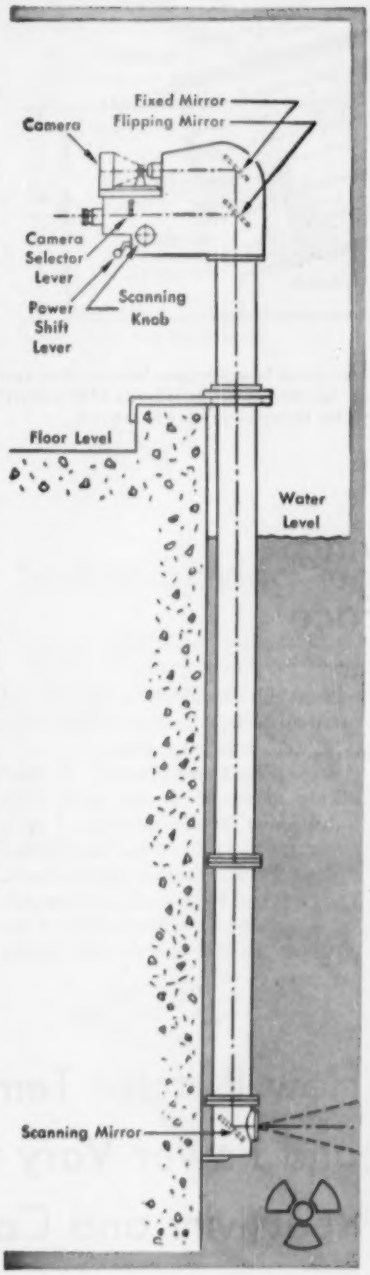

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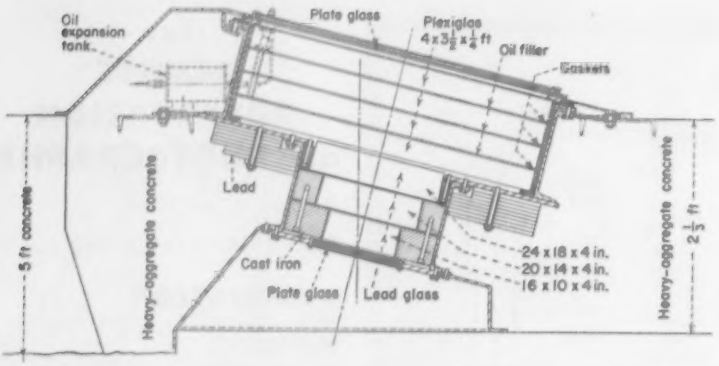


SHIELD-WINDOW assembly arrangement allows space in wall recess for two observers and control equipment. Part of wall having reduced thickness is made of 270-lb/ft³ concrete; sheets of lead are added where even the heavy concrete was too thin

Characteristics of the Window

Angle of incidence (deg)	*Light transmitted (%)*	*Resolution (sec)*
90	47	10
75	47	10
60	45	14
45	44	14
30	40	24
15	24	34
10	11	—

Windows for Viewing Hanford Reactor Face

By L. T. PEDERSEN
Engineering Department
*Hanford Atomic Products Operation**
Richland, Washington

By means of two windows in the shield of a Hanford reactor, remote operations and maintenance procedures involving intricate equipment can be observed over an area of about 80 ft² on the rear face of the reactor. Each 2-ft-thick window, whose complete assembly costs $9,500, gives the same protection as 5 ft of ordinary concrete.

As shown in the figure, each window consists of 12 in. of Plexiglas for neutron shielding and 12 in. of lead silicate glass for gamma shielding. The window's characteristics are shown in the table.

The Plexiglas has good light transmission and resolution, and its 8% hydrogen makes it a good thermal-neutron shield. Since sheets 3 in. thick were the largest commercially available, four of them are clamped together. To improve the light transmission by eliminating the reflection at the surfaces, clear mineral oil with the same refraction index as the Plexiglas is placed between the layers. Edge gaskets seal each layer. Since the mineral oil adequately hides internal surface defects, only the two outer surfaces were polished extensively.

The 6.2-gm/cm³ density of lead silicate glass, which has good light transmission for all colors except blue, makes the glass about half as effective as lead for attenuating gamma rays. The glass had to be made in three sections because of the limited size of the platinum crucible used for melting the lead silicate. A low-reflective coating reduces light loss at the surfaces.

Chromatic aberration, caused by the different indices of refraction for varying wave lengths or colors, is avoided by illuminating the subject with sodium light, which essentially has only one wave length.

Consideration was given to the use of distilled water as the transparent shielding medium. Distilled water has been used extensively on previous installations. With this type, algae growth has caused some viewing difficulty and leaks are very dangerous because a partially filled window exposes the viewer to the radiation. Since a 10-ft thickness of water would be needed, and only a small window space was available for observing the large area, water was rejected in favor of the thinner solid window.

*Operated by General Electric Co. for the U. S. Atomic Energy Commission.

How Reactor Temperature and Power Vary with Reactivity and Cooling

By H. GAUS and R. SCHULTEN
Max-Planck-Institut für Physik
Göttingen, West Germany

For a natural-uranium graphite reactor in stationary state, the usual diffusion theory combined with Fermi age theory yields only the spatial shape of thermal-neutron flux—and not the amount of flux or power. The power is determined by the cooling of a system with temperature T' fixed by $k_{eff}(T) = k_{eff}(T_0) - \Gamma(T - T_0)$, and $k_{eff}(T') = 1$; where k_{eff} is a function of temperature and is equal to the reactivity minus the loss due to poisoning, control rods, and other neutron absorption and leakage.

If these relationships are introduced

into the reactor equations, and relationships are applied between uranium temperature, coolant temperature, power, and neutron flux, we get a nonlinear differential equation to determine the neutron flux of a reactor. The solution of this equation is approximated by

$$\phi = A \cos(\pi 2/l')J_0(2.405r/R')$$

and A is determined by a variational method. Thus

$$A = \left(\frac{\pi}{l'}\right) jc_p(T' - T_0)/[(2ljc_p/l'F\alpha) + \sin(\pi l/2l') + R]$$

$$R = \frac{\left\{\left(\frac{\pi^2}{2} - 4\right)\left(\frac{ljc_p}{l'F\alpha}\right)^2 + \frac{1}{2}\left(1 + \frac{\pi^2 L^2}{2\Gamma D_{avg} l'^2(1 + L^2B^2)}\right)\right\}}{2(ljc_p/l'F\alpha) + \sin(\pi l/2l')}$$

We also get approximate expressions for the coolant and uranium temperature as a function of T' and the cooling parameters. The maximum temperature of the uranium, a value especially important for evaluating structural materials, is

$$T_{max} = (T' - T_0)\left[\frac{\sqrt{1 + \left(\frac{\pi ljc_p}{l'F\alpha}\right)^2} + \sin\left(\frac{\pi l}{2l'}\right)}{2\,\frac{ljc_p}{l'F\alpha} + \sin\left(\frac{\alpha l}{2l'}\right) + R}\right]$$

For fluxes that are not too high, we also get an approximate solution for the shape of the flux showing a slight shifting to the colder side of the reactor.

Temperature rise after cooling failure. If the power level of an internally cooled reactor is changed by altering reactivity, δk, its behavior can be described by

$$t_0\, dQ/dt = (\delta k_0 + \delta k - \Gamma T)Q - \int_0^t D(t - t')[dQ(t')/dt']\, dt'$$

$$E\, dT/dt = Q - AT$$

$$D(t) = k_{eff} \sum_i \beta_i e^{-\lambda_i t}$$

where $t = 0$ is the time when the stationary state ends. At this time, the change is particularly important if an accident causes the cooling system to fail and A becomes zero. Then the power decreases to zero and the temperature asymptotically approaches a limiting value given by

$$T - T_0 = (1/\Gamma)(\delta k + \sqrt{(2Q_0\Gamma/E)t_{avg} + (\delta k)^2})$$

$$t_{avg} = t_0 + k_{eff} \sum_i \beta_i/\lambda_i$$

Symbols

A = reactor heat-transfer coefficient
B = buckling
c_p = specific heat
D = coolant temperature
E = reactor heat capacity
F = surface area of a uranium lump
j = cooling current
L = diffusion length
l = length of reactor
$l' = l + 2\delta$
Q = reactor power
R = radius of reactor
$R' = R + \delta$
T = uranium temperature
T_0 = temperature in stationary state
t_0 = lifetime of a thermal neutron
α = heat-transfer coefficient
β_i = fraction of delayed neutrons
Γ = temperature coefficient of reactivity
δ = reflector saving
δk_0 = reactivity, that is, compensated by ΓT_0

The time period of the approximation to the end-state is given by

$$\tau = \frac{2t_{avg}}{\sqrt{\frac{2t_{avg}Q_0\Gamma}{E} + (\delta k)^2}}$$

The additional temperature rise caused by the delayed β- and γ-rays must be considered separately.*

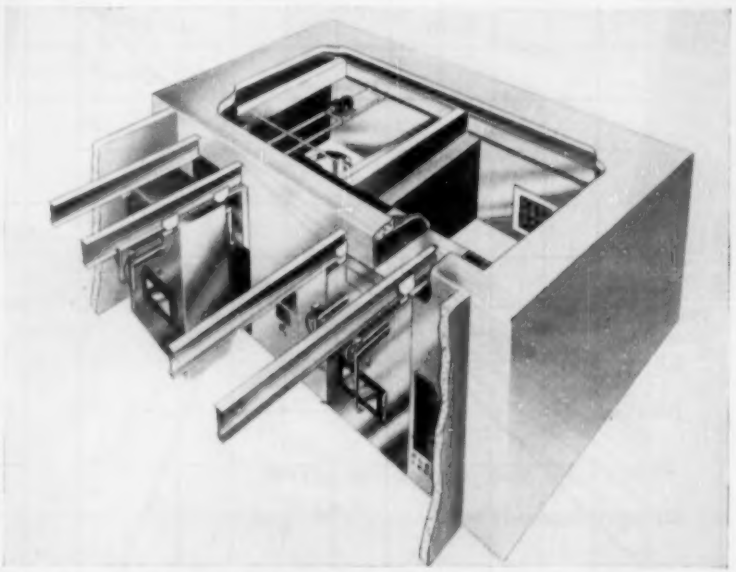
* For details on these calculations, see *Z. Naturforsch.* **9a**, pp. 964 and 1039 (1954).

Space-Saving Hot Cell

By M. C. ATKINS and W. N. LORENTZ*
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio

* PRESENT ADDRESS: Westinghouse Atomic Power Division, Pittsburgh, Pa.

Saving of space was a primary consideration in the design of a general-purpose hot cell being built for radiochemistry, metallurgical work, or Co^{60} irradiation experiments. The cell can be built in one end of an existing room



Cell has two 7 × 7½-ft chambers divided by a steel and magnetite partition, which can be rolled on tracks through the back wall to give a 7 × 18-ft chamber. Three walls of hot cell are formed by existing walls of room with 33 in. extra concrete around outside. Operating face and plug-type access doors (although not shown here, doors are stepped) consist of steel forms containing 36 in.of packed magnetite ore; top shielding is provided by 18 in. of magnetite packed between existing concrete roof slabs and a suspended steel plate. Magnetite-in-steel-forms construction gives great flexibility at low cost. All inside surfaces of the cell are of steel

because the access doors are in the operating face rather than at the rear of the cell.

As shown in the figure, each of the two chambers has a window and a pair of ANL Model-8 master-slave manipulators mounted in its access door. Each chamber can shield 1,500 curies; for cobalt irradiations, stacking 12 in. of concrete block around the outside of the wall increases the cell's capacity to 20,000 curies. Total cost of the cell, which is scheduled for completion by December 1, 1955, will be $120,000, not including the manipulators.

Windows. From the inside out, the zinc-bromide windows consist of 1-in. nonbrowning glass, 36-in. optical-grade zinc bromide solution, 1-in. polished plate glass, and 3-in. 6.2-density lead glass. Periscopes easily can be installed in through-tubes in the doors; the tubes now are filled with magnetite and capped.

Crane. A 2-ton traveling-bridge crane serves both compartments and is controlled from the operating face. The space between the top of the partition and the steel ceiling is filled by one of two steel slabs rolling on the same level as the crane. The slabs, which are connected rigidly a chamber length apart, are moved by the bridge motor so that one slab always will be over the partition when the crane is in either chamber.

Utilities. Permanently installed in the cell are water, demineralized water, gas, air, and spare pipes, and four types of electric power. In each chamber, six through-tubes with spiral-grooved aluminum plugs permit quick installation of additional facilities and control lines. The cell also has a CO_2 fire-extinguisher system and a remote radiation-monitoring system.

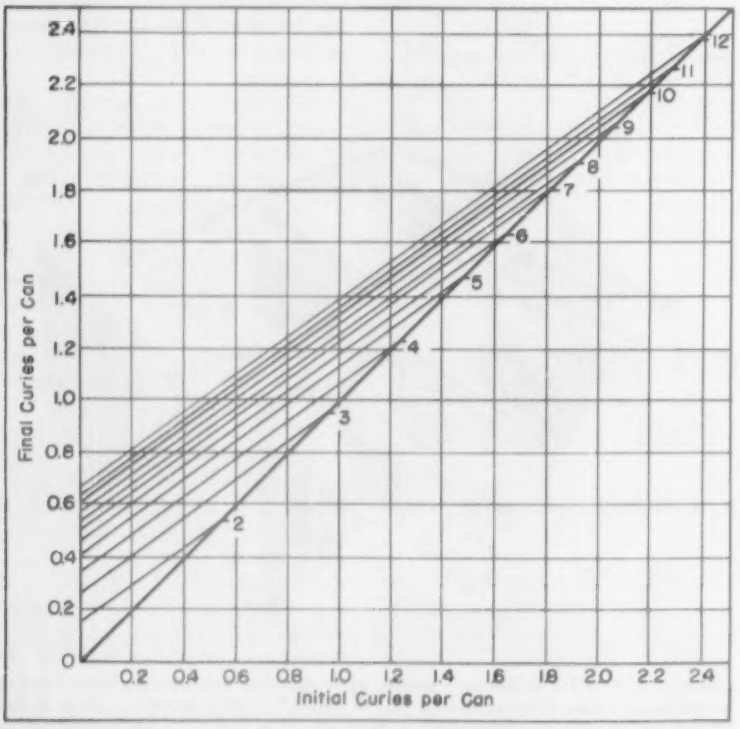
Storage. Two facilities in the cell provide for storage. A 10-curie sample can be stored in each of the twelve horizontal tubes in the vault in the right-cell wall. High-activity items, such as Co^{60} sources, can be stored in a 17-ft-deep water-filled well in the left cell. The well has a type-347 stainless-steel shell and is provided with a circulating pump, water deionizer, and an electrically operated elevator.

* * *

Detail designed by R. V. Harty Co., Inc., Detroit, Mich.; design project engineer is G. E. Parker.

Graphical Method Speeds Production Scheduling of Radioisotopes

By A. D. ROSSIN, C. J. BILLERBECK, W. S. DELICATE, A. W. WENDLING, A. S. HOFFMAN, and R. C. REID
Massachusetts Institute of Technology, Engineering Practice School, Oak Ridge, Tennessee



GRAPH for determining weekly production of phosphorus-32 at 12 locations in hole 16 of the Oak Ridge Graphite Reactor. To use the graph: locate on the abscissa the activity of a can at time of placement (zero for a fresh can); project vertically to the line for the can position; project the intersection to the ordinate to get the activity in the can after 1 week irradiation at that position

An economical process for producing radioisotopes in a reactor requires careful planning. Reactor space must be used as efficiently as possible and still obtain a product in which the concentration of the desired isotope is high enough so that it may be separated from the remaining untransformed material without excessive cost. This article presents a simple graphical method for determining the activity of irradiated material at any stage of a production cycle. The results obtained and the limitations imposed by the separation process may be used to determine optimum scheduling.

In a batch irradiation process,[1] small quantities or packets of fresh feed material are put into a beam hole during each reactor shutdown and product cans are removed from the region of the hole where the flux is highest. Meanwhile, the remaining cans in the hole are moved toward the highest-flux region so as to allow activity to be built up. Since the rate at which the radioisotope decays is proportional to its concentration, the highest net rate of production occurs if packets are fed through the pile rapidly. However, the concentration thus obtained is so low that the load on the processing equipment becomes excessive. An eco-

nomic balance must be reached with some lower production rate that yields packets of such concentration that the separating equipment can handle them.

The method. An actual case best illustrates the method. Reactor shutdown times and fast-flux levels used here are based on the ORNL Graphite Reactor, but with only slight modification, the method is applicable to other reactors. Production of P^{32}, formed by the reaction $S^{32}(n,p)P^{32}$, uses neutrons having energies over 2.29 Mev. Cans of sulfur are fed into and removed from the beam hole during shutdown; in the case considered here, there is a maximum of 12 cans in the hole at any one time. These cans extend from the outer core boundary to slightly beyond the core center.

The net rate of production of P^{32} atoms in the reactor depends on the difference between the rate at which P^{32} atoms are formed by neutron interaction with sulfur atoms and the rate at which P^{32} atoms decay (by beta emission) to S^{32}. The net rate is

$$(dN/dt) = \sigma n\phi - N\lambda \qquad (1)$$

where N is the concentration of P^{32} atoms present at time t, ϕ is the fast-neutron flux ($E_n > 2.29$ Mev), n is the concentration of sulfur atoms, σ is the microscopic cross section for the $S^{32}(n,p)P^{32}$ reaction, and λ is the decay constant for P^{32}. The factors σ and λ are constants in Eq. 1, n may be assumed constant, but ϕ is a function of the position of the sulfur in the reactor. However, since there is no continuous movement of cans through the reactor, ϕ may be considered constant over the time of irradiation when a can remains in a single position in the reactor. With this limitation, Eq. 1 may be integrated to become

$$N = \left(\frac{\phi n\sigma}{\lambda}\right)_L (1 - e^{-\lambda t}) + Ne^{-\lambda t} \qquad (2)$$

The subscript L indicates that the first term is a constant only at the one position L in the reactor. N is directly proportional to the activity in curies per can,* as can be seen from the definition of the curie

$$C = [(N \text{ atoms/cm}^3)(1{,}200 \text{ cm}^3/\text{can})(0.0485 \text{ decays/atom/day})/(86{,}400 \text{ seconds/day})(3.7 \times 10^{10} \text{ decays/curie/sec})] = 1{,}82 \times 10^{-14} N \text{ curies/can} \qquad (3)$$

* Aluminum cans used at ORNL are 3.5 in. in diameter and 13 in. long. Each contains about 1,200 cm³ of elemental sulfur.

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Equations 2 and 3 may be combined to yield

$$C = 1.82 \times 10^{-14}(\phi n\sigma/\lambda)_L(1 - e^{-\lambda t}) + C_0 e^{-\lambda t} \quad (4)$$

For the case under discussion, since the reactor is only opened once a week, cans can be moved only at weekly intervals, hence t can be taken as 7 days; $\lambda = 0.0485$ days^{-1}, $\sigma = 0.028 \times 10^{-24}$ cm^2, $n = 0.389 \times 10^{22}$ atoms of sulfur per cm.^{3} Thus, Eq. 4 can be written

$$C = 0.288\,(1.82 \times 10^{-14} \times 1940\,\phi_L) + 0.712\,C_0 \quad (5)$$

Calculation of C requires information regarding the fast flux, ϕ_L, as a function of position. This was obtained by experimentally measuring the conversion of S^{32} to P^{32} at various points in the irradiation hole. The results are shown in the table.

Fast-Flux Distribution in Hole 16 of ORNL Graphite Reactor

Can position	ϕ_L *(10^{13}n/cm^2/sec)*	*Distance from south face (ft)*
1	0.5	28.2
2	1.5	27.1
3	2.7	26.0
4	3.5	24.9
5	4.1	23.8
6	4.6	22.7
7	5.1	21.6
8	5.5	20.5
9	5.8	19.4
10	6.2	18.3
11	6.5	17.2
12	6.7	16.1

By using the data in the table to obtain ϕ_L in Eq. 5, the curies per can after an irradiation time of 1 week can be expressed as a function of initial curies/can and reactor position. Each of the 12 lines in the figure is a plot of Eq. 5 for one of the 12 can positions used. Its intercept with the 45-deg line reveals the concentration obtainable if the can were irradiated at that position for an infinite period of time, the rate of production then being equal to the rate of decay.

Example. To illustrate the use of the figure, consider the present production schedule. During shutdown, four sulfur cans are loaded into the reactor beam hole and left there for 2 weeks. They initially occupy can positions 1, 2, 3, and 4, respectively. After 1 week, the activity in can 3, for example, increases from zero to 0.27 curies ($C_0 = 0$ at position 3). During the succeeding week, the can remains at position 3 and the activity increases from 0.27 curies ($C_0 = 0.27$) to 0.46 curies. At the next shutdown period, four new cans are inserted, and the can considered above moves up four positions to position 7, where it remains for another 2 weeks. For $C_0 = 0.46$, a can at position 7 for a week increases in activity to 0.83 curies. The graphical calculation is repeated for the next week and then the can, which now has an activity of 1.10 curies, is moved up four more positions. It then remains at position 11 for 2 weeks as its activity increases to 1.66 curies. Likewise, the cans originally inserted in positions 1, 2, and 4 are removed from the reactor with activities of 1.35, 1.53, and 1.78 curies, respectively. The sum of the activities of the four cans equals 6.32 curies, which represents the production of P^{32} for the beam hole in a 2-week period.

Other product activities similarly may be calculated as functions of the number of cans that must be fed and processed per week to obtain the desired radioisotope-production rate.

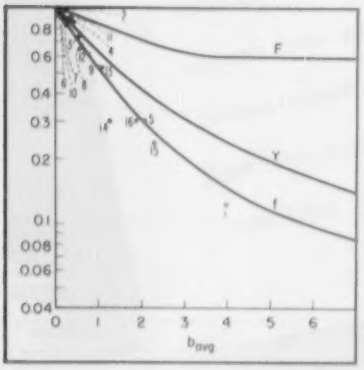

FIG. 1. Flux depression (F), total perturbation (f), and average attenuation in sample (Y) as a function of average number of relaxation lengths in a path length through sample (b_{avg}). Curve f is fitted to experimental points from samples in table

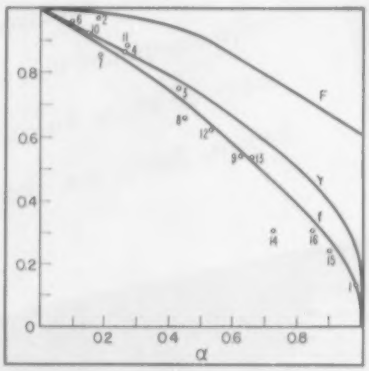

FIG. 2. Flux depression (F), total perturbation (f), and average attenuation in sample (Y) as a function of "greyness" of sample (α)

Flux Perturbations by Material Under Irradiation

By WM. BRADLEY LEWIS

Phillips Petroleum Co.
Idaho Falls, Idaho

A semi-empirical method can be used to determine the effective flux throughout a sample in a reactor because the perturbation factor is a function of the ratio of average chord to relaxation length. The justification of the method lies in the results, which have proved applicable and useful to a high degree. Data were gathered at the Materials Testing Reactor (NU, April '54, p. 20), and the results apply strictly to the MTR. But similar curves could be obtained for other reactors.

Material irradiated in a neutron atmosphere absorbs neutrons at a rate proportional to the neutron flux. To calculate this rate, the flux must be known at each small element of the sample's volume. This flux differs from the flux that would exist if the absorptive material were absent.

The sample perturbs the flux by: (a) attenuating it inward from the surface of the sample, and (b) depressing it near the sample. Attenuation results from progressive absorption of neutrons as they penetrate the sample. Depression is caused by the flux gradient that comes into existence when a neutron sink is introduced into the neutron field.

The usual analytical treatment

involving the diffusion equation presupposes symmetry and boundary conditions that are not even roughly approximated in practical situations. So this attack has been abandoned in favor of a semi-empirical approach.

Development

Two rigorous equations describe the rate at which neutrons are captured by a sample in terms of physical and geometric parameters. One may be termed the "surface equation"

$$x = p_{avg} F \phi S/4 \qquad (1)$$

and the other, the "volume equation"

$$x = f \phi V/\lambda \qquad (2)$$

In general, it is not possible to calculate p_{avg}. The quantity $p(b)$ is a function of the path length through the sample. This length is a function of four parameters, two of which are required to locate a surface element in terms of arbitrary surface coordinates, and two of which are required to deter-

Symbols

A = atomic weight of sample
$b = L/\lambda \equiv$ number of relaxation lengths in distance L
F = ratio of effective flux to unperturbed flux at sample's surface
f = experimentally determined factor to make Eq. 2 rigorous
L = path length through sample
$p_{avg} \equiv [p(b)]_{avg}$ = average probability of capture
$p(b)$ = probability of capture along a path whose length is λb
S = surface area of sample
u_{avg} = weighted average of u taken over all paths through sample; weighting factor is cosine of angle between path and normal to surface at point of entry
V = volume of sample
x = rate of neutron capture by sample
$Y = \alpha/b_{avg}$ = average attenuation in sample
y = fraction of graphite surface covered by cobalt
$\alpha = p(b_{avg}) = 1 - \epsilon^{-b_{avg}} \approx$ probability of capture along path whose length is $L_{avg} = b_{avg}\lambda$
$\lambda = (N\sigma\rho/A)^{-1}$ = relaxation length for sample material
ρ = density of sample
σ = absorptive cross section of sample
ϕ = unperturbed value of neutron flux

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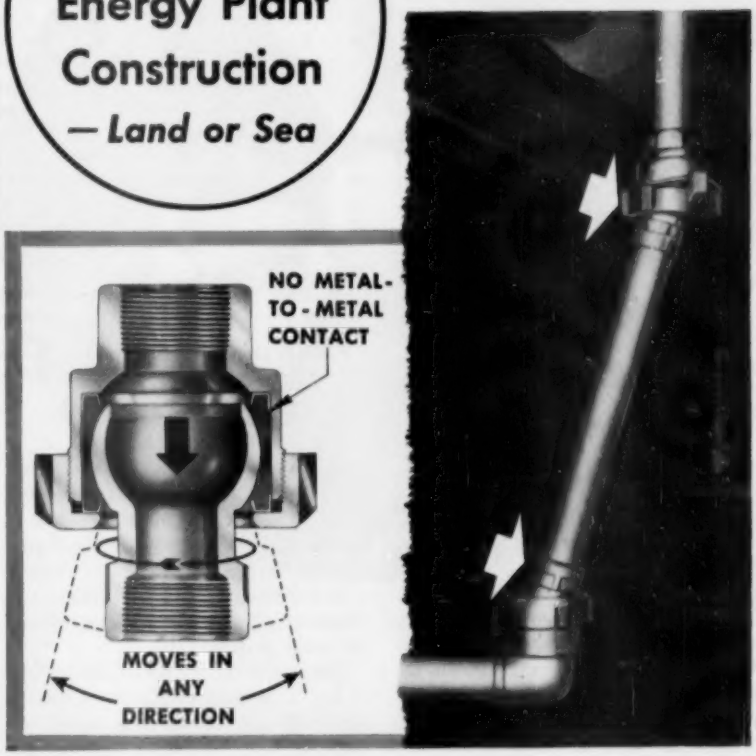

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mine the direction of the path relative to the surface element. For an arbitrary shaped surface, the analytical expression for the average of $p(b)$ can not be evaluated.

As an approximation we will substitute α for p_{avg}, where α is the probability of capture along the average path

$$L_{avg} = 4V/S \qquad (3)$$

This expression is derived from general geometric considerations and holds for arbitrary shapes. However, we will limit consideration to surfaces pierced in no more than two points by an arbitrary straight line.

To return to the desired probability, the expression

$$p(b) = 1 - e^{-b} \qquad (4)$$

gives the probability that a neutron is captured in traversing a path whose length is $L = \lambda b$.

We have approximated p by α. Actually,

$$p_{avg} \leq p(b_{avg}) = \alpha = 1 - e^{-b_{avg}} \qquad (5)$$

The two quantities are equal when b_{avg} is zero, and both p_{avg} and α approach unity as b_{avg} becomes large. The approximation is good throughout the range of b_{avg}. The inequality can be derived from the well-known inequality that the geometric mean does not exceed the arithmetic mean.

So from Eq. 1, it follows that

$$x = (S/4)p_{avg}F\phi \approx < (S/4)\alpha F\phi \qquad (6)$$

and from Eqs. 6 and 2 it follows that

$$(f/F) = (S/4)(\lambda/V)p_{avg} = (p_{avg}/b_{avg}) \approx < (\alpha/b_{avg}) = Y \qquad (7)$$

The symbol Y is introduced for convenience.

Discussion

It now remains to determine the values of f or F; in most cases f will be found. Samples of known dimensions and compositions are irradiated in regions of known unperturbed flux. The amount of product is determined experimentally, and f is determined directly from Eq. 2.

Since the parameter b_{avg} involves averaging a path length over the sample, it might be expected that shape and symmetry factors would be eliminated and that b_{avg} would be the significant parameter. To what extent this is so is shown in Fig. 1 where the curve f is fitted to the experimental points obtained from samples of various shapes and sizes as shown in the table.

Along with f are plotted the theoretical curve Y, and the derived curve F. The Y-curve serves as a helpful guide as the f-curve must lie below it and the F-curve above it. Both Y and f vanish for b_{avg} infinite; F approaches a nonvanishing positive quantity. These are aids in extrapolating beyond the range of data.

The vanishing of f for infinite values of b_{avg} is implied in Eq. 2. Unless f vanishes, the capture rate would become infinite. Similarly the nonvanishing of F follows from Eq. 1. As b_{avg} becomes infinite, p_{avg} approaches unity, and the rate does not vanish; so F cannot vanish.

The physical significance of the quantities is now clear; α, which is very nearly equal to p_{avg}, measures the "greyness" of the sample. For a perfect absorber, or black sample, α is unity; for a perfectly transparent sample, α is zero. The symbol F measures the flux depression; f measures the total perturbation. Thus Y is a measure of the average attenuation in the sample.

Throughout this discussion it has been tacitly assumed that there is no "coupling" between the sample and the neutron source. A direct implication of this assumption is that as the greyness of the sample is increased, the rate of capture of neutrons continually increases. In other words, there can be no extremum in the rate of capture. This implies that the product αF is monotonely increasing with α. This can be true only if $F(1) \geq -(dF/d\alpha)_{\alpha=1}$, which makes $F(1) \geq 1/2$.

These conditions, viz: that the function $\alpha F(\alpha)$ is monotonely increasing, and that $F(1) \geq 1/2$, set fairly rigid limits on the shape of the F vs α curve. The smallest value of $F(1)$ consistent with the experimental data is $F(1) = 0.6$. This determines the shape of the F-curve, and hence the f-curve, very closely. Figure 2 shows the three curves plotted against α.

Data for Various Samples Irradiated in MTR

No.	Sample	Diameter (in.)	Length (in.)	L_{avg} (in.)	λ^{-1} (in.$^{-1}$)	b_{avg}	α	f
1.	U^{235}	0.050	5	0.050	79.5	4.01	0.982	0.122
2.	U_{nat}	0.188	1.00	0.176	0.97	0.201	0.182	0.97
3.	Au	0.040	*	0.040	14.2	0.566	0.432	0.75
4.	Co	0.040	*	0.040	7.82	0.330	0.26	0.87
5.	Co	0.295	1.18	0.262	7.82	2.05	0.872	0.30
6.	Co	0.020	0.017	0.0126	7.82	0.0985	0.097	0.960
7.	Co	0.040	0.036	0.0257	7.82	0.203	0.183	0.854
8.	Co	0.119	0.118	0.079	7.82	0.617	0.450	0.654
9.	Co	0.186	0.188	0.124	7.82	0.975	0.620	0.537
10.	Co	0.020	0.250	0.0199	7.82	0.155	0.144	0.920
11.	Co	0.040	0.250	0.0397	7.82	0.311	0.268	0.887
12.	Co	0.119	0.250	0.0961	7.82	0.752	0.528	0.613
13.	Co	0.186	0.250	0.136	7.82	1.062	0.653	0.530
14.	U_{nat}	1.5	*	1.5	0.85	1.28	0.722	0.30
15.	Co	0.312	3.0	0.269	7.82	2.31	0.899	0.238
16.	Co	0.240	12.0	0.240	7.82	1.88	0.848	0.30

* Length not known, but large compared to diameter.

Application

Since the data points were all based on samples of simple geometric shapes, an example will be chosen that extends the method to a fairly complicated geometry. An array of cobalt disks, 2 cm diameter and 1 mm thick are set on opposite faces of a square graphite prism.

Analysis is based on the simple and reasonable assumptions that (a) the disk's two faces are exposed to different fluxes, an outer flux ϕ_o and an inner flux ϕ_i; (b) the inner flux consists of neutrons that enter the graphite (nonabsorptive medium) directly, plus those that are attenuated by traversing the cobalt disks. Thus

$$\phi_i = \phi_o(1 - y) + \phi_o y e^{-b_{avg}} \qquad (8)$$

$$\phi_{eff} = (1/2)(\phi_o + \phi_i) = \phi_o(1 - \alpha y/2) = \phi F(1 - \alpha y/2) \qquad (9)$$

We shall use this value of effective flux in Eq. 1 to calculate the specific activity of the cobalt. Interaction between disks of the assembly, other than those here considered, is assumed to be negligible.

For this array, we find: $\lambda^{-1} = 3.07$ cm, $L_{avg} = 0.1818$ cm, $b_{avg} = 0.558$, $y = (1/2)(\pi d^2/4d^2) = (\pi/8) = 0.3927$,

mass of disk = 2.75 grams, $\alpha = 0.425$, $F = 0.90$, $t_{1/2} = 1.67 \times 10^8$ sec.

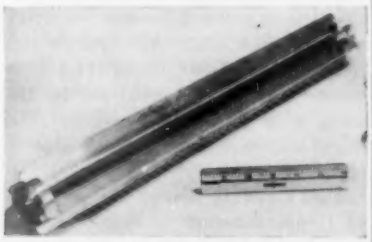
Since each capture produces 1 atom of Co^{60}, we have $n = (S/4)\alpha F(1 - \alpha y/2)\phi t(0.864 \times 10^{19})$, where t is time in days, and $\phi \times 10^{14}$ is neutron flux in neutron cm^{-2} sec^{-1}. Disintegrations per second are $n(\ln 2/t_{1/2}) = 4.15 \times 10^{-9}n$. Thus, the total curies is $A = n(4.15 \times 10^{-9}/3.7 \times 10^{10}) = 1.12 \times 10^{-19}n$, and the specific activity, $a = (A/2.75)$ curies/gram. So, $a = 0.0970\phi t$.

For the sample taken, $\phi t = 287$; the measured specific activity was 31 c/gm. So we compare the calculated a of 28 c/gm with the measured a of 31 c/gm, and conclude that, in view of the inherent errors in the assumed values for flux, the agreement is excellent.

Experimental Data

The actual activities in the table were determined by a number of means—samples 1 and 2 by fission-product analysis; samples 5, 15, 16 by comparison with a standard cobalt source; samples 3, 4, 6–13 were measured by standard counting techniques; sample 14 was analysed by observing the rate of production of fission heat. The chief source of error in determining f lies in the assumed value of the unperturbed flux. Although extensive flux measurements have been made in the MTR, there have been only a few indirect measurements of nvt (flux averaged over an extended time interval). The probable accuracy of the values used is about $\pm 20\%$.

REACTOR FACTS



Highly enriched fuel element made by Sylvania for Brookhaven consists of three strips of U-in-Al sandwich, bent at 60 deg., and held by 2.5-in.-diameter rings at each end

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needed for pumping the air coolant to 1,000 kw, rather than 5,000 kw now needed. Power level at the higher flux will be 20 Mw, compared to present 30 Mw. About 50 kg of U^{235}, distributed over the same number of fuel channels as now used, will be required.

The fuel elements under development (UN Geneva conference paper *860*) are fabricated from MTR-type fuel plates. Each plate will be 2.25-in. wide by 24-in. long by 0.060 to 0.080-in. thick, and will contain only 3 to 4 grams of U^{235} imbedded in an aluminum matrix and clad with aluminum. These plates are bent into a 60 degree angle. There will be eight fuel elements in each fuel channel, for a total of about 5,000.

Although MTR-type fuel plates have never been operated in other than a water-coolant medium at low temperatures, the tests, so far, indicate that they can be used with air cooling at much higher temperatures with good service life and high burnout. Failures are expected to be much less frequent than with the solid rod, natural-uranium fuel elements. In fact, the whole operation of the Brookhaven reactor will be much simpler when the reloading has been accomplished.

The change of fuel will have a marked effect on all the neutron-physics aspects of the reactor. This is due to the removal of the U^{238}, which represents a very great poison in the core. The neutron generation time, at present about 1.5 milliseconds, will be about 6 milliseconds. This means that every poison will have a larger reactivity effect than now, and that the response to excess reactivity will be more sluggish. The control rods will represent about 14.8% in excess reactivity in contrast to the 4.3% with the present loading. The shield will require no modifications to take care of the increased flux.

Fuel elements now in use are made of 1.1-in. diameter U slugs inside a finned aluminum tube, 11.5 ft long, with 2.37-in. fin-tip to fin-tip diameter. Slugs are each 4-in. long. A system of helium pressure monitoring guards against undetected failure of the aluminum jacket.

Modification of MTR fuel elements has improved performance. R. L. Doan and J. R. Huffman of Phillips Petroleum Co., operator of the Materials Testing Reactor for AEC, described at Geneva how relatively small

changes to MTR's fuel elements have improved the reactor's performance.

Fuel is highly enriched uranium in 3 × 24-in. (approx.) plates of aluminum-clad Al-U alloy in assemblies of 18 or 19 vertical plates. Cooling water flows between the plates. Assemblies can be loaded in any lattice configuration up to a 5 × 9 array. A 3 × 9 array usually is used; a 5 × 5 array gives higher reactivity for a given uranium content, but provides fewer beam holes with high fast flux.

For the first 30-Mw operation, the reactor contained 23 fuel assemblies and four fuel-shim rods in a 3 × 9 configuration. The fuel assemblies each contained 140 gm U^{235} and shim rods contained 110 gm U^{235} each (active mass = 3,660 gm U^{235}). Rods initially were withdrawn only 16½ in. Charge No. 1 produced 376 Mwd (12½ days at full power) and average fuel burnup was about 13%.

Later, to get higher reactivity, fuel contents of fuel assemblies and shim rods were increased 20% (168 gm and 132 gm, respectively); these gave 740 Mwd and burnup of 21%.

Another small reactivity increase was gained by reducing the thickness of the fuel-assembly side plates from 3/16 in. to ⅛ in.

Since May, 1954, the fuel content of each assembly has been 200 gm U^{235} and a 3-week cycle has been used (about 40% burnup).

These changes and others involving shifting location of elements at each loading have decreased changes of fuel elements and shim rods from original 6 and 1 per 100 Mwd to 1.5 and 0.1, respectively.

Sodium-graphite reactors show promise. Chauncey Starr of North American Aviation, in speaking at Geneva of the Sodium Graphite Reactor said that if he uses Th-U^{235} he'll get 100 Mw power, 0.9 conversion ratio, $265/kw, and 8.5–9.5 mills/kwh power (with U^{235} costing $15–30/gm). In the future, if they can get Th temperature of 1,100° F, then they'll get 650° F Na temperature, 125 Mw power, >0.9 conversion ratio, $200/kw, and 6–7 mills/kw power.

Starr was asked whether they'd considered using unclad uranium elements. He said, not really, but that they planned to study this with SRE. Apparently, it may be quite possible and desirable (economically) to use unclad fuel with Na as coolant. Both Na and U have to be very pure so that

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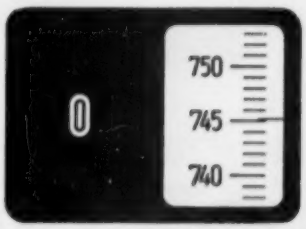

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they can be in contact with each other.

Status of LMFR. In a paper presented at Geneva, F. T. Miles and Clarke Williams of Brookhaven National Laboratory said that most of the basic chemical and metallurgy problems of liquid-metal-fuel reactors have been solved. Many small loops have been operated outside of neutron radiation fields. Presently, one chemical processing loop is being operated at a flux of 10^{16} n/cm²/sec in the Brookhaven reactor. Engineering developments have been started on pumps, heat exchangers, and chemical-processing columns. Exponential assemblies of uranium, bismuth, and graphite will be made beginning sometime in 1956. It is planned to push the testing of the various large-scale components so that in late 1957 or 1958 construction can start on some form of experimental or prototype reactor. If it were considered desirable to operate such a reactor as a U^{235} burner without breeding, it might be possible to achieve reasonably significant power levels, 10 to 50 Mw, at that time. However, to achieve large-scale plants with breeding ratio approaching 1 it will take several years after the operation of the reactor experiment, that is, sometime in the early 1960's.

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TECHNICAL ADVANCES

Einsteinium, Fermium From H-Bomb Debris In December, 1953, when UCRL and Argonne radiochemists announced the production of elements 99 and 100 in the high neutron flux of the MTR they noted that there was earlier unpublished information on those elements and hence that the question of priority should not be prejudged. The mystery is cleared up with declassification of the fact that elements 99 and 100 were identified in bomb debris from the November, 1952 thermonuclear explosion ("Mike" test). The discovery was through a cooperative effort of UCRL, Argonne, and Los Alamos groups using ion-exchange techniques for separation of the actinides. They suggest the names einsteinium (symbol E) for element 99 and fermium (Fm) for element 100 after Albert Einstein and Enrico Fermi, respectively.

Isotopic assignments made for the elements have been confirmed by the subsequent MTR irradiations. Fm^{255} emits a 7.1-Mev alpha with 16-hr half-life. It is produced from beta decay of 30-d E^{255}, itself a descendant of U^{255} formed in the massive instantaneous H-bomb neutron flux by the capture of 17 neutrons in U^{238}. Einsteinium was identified via 20-d E^{253} a 6.6-Mev alpha emitter which is the end product of a series of beta decays beginning with U^{253}.

"Hard Bottoming" Multivibrators The "on" or conducting state of two-state circuits can be made extremely stable by pulling the plate voltage down to very low values that can be maintained throughout the life of the tube. Thus, scaler or multivibrator operation is made stable even in face of large changes in tube characteristics. In fact, variations from tube to tube and even among similar tube types affect things much less than in conventional operation. Hence useful tube life is longer and operation more dependable.

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C. C. Harris of ORNL's Physics Division reported this work at last month's meeting of the Professional Group on Nuclear Science of the IRE. The technique is not a new one, but somehow has not been used broadly.

Sources of Background in NaI Counting As part of a study of the Ra content of humans, C. E. Miller, L. D. Marinelli, and J. E. Rose of Argonne National Laboratory have taken a careful look at the sources of background in their scintillation crystal.

For an unshielded 4- × 1½-in. NaI crystal the background is 7,000 cpm in the 0.090–2.5-Mev region of the spectrum. Shielding the crystal in a special room with 8-in. of steel on all sides, the count is lowered to 480 cpm. Adding 1 in. of Hg around the crystal reduces the background to 360 cpm.

The spectrum of this residual background strongly suggested that it might be largely due to Ra. The fact that the 1-in. layer of Hg had not reduced the background more than it had suggested that the source of background was within that shield. Measurement revealed that samples of Al, regardless of alloy type or supplier, averaged 0.3 $\mu\mu$c of Ra per gram of Al. The crystal had been canned in Al; remounting the crystal in a stainless-steel can with quartz window reduced the background to 150 cpm. Of this some 15 cpm is due to betas from the 8 ppm by weight of K in the NaI crystal. No activity, either beta or gamma, was found in the MgO reflector or the Tl activator, but the 0.1% K in the 5-in.-photmultiplier glass contributes 35–45 cpm. Placing a G-M counter ring so as to anticoincidence cosmic rays removed 38 cpm, leaving some 55 cpm of unknown origin in the 0.09–2.5-Mev range.

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BOOKS

Geneva Conference Proceedings

The Proceedings of the Geneva International Conference on the Peaceful Uses of Atomic Energy will be published by the United Nations in 16 volumes of approximately 500 pages each. The series will comprise all papers, oral or written, and the discussions.

The series will be available in English in January, 1956—the first one, Vol. 3 (Power Reactors), in November, 1955. The French and Spanish editions will be available late in 1956.

A special prepublication price of $110 (USA), £39, or 450 Swiss francs for the full series applies to orders received up to December, 1955. Orders for the series or for individual volumes (prices to be announced) may be placed with the UN sales agents or the UN Headquarters Bookshop. (Individual papers are also available from the Bookshop at $.25 each.)

The volume titles are: 1, The World's Requirements for Energy: the Role of Nuclear Power; 2, Physics, Research Reactors; 3, Power Reactors; 4, Cross-Sections Important to Reactor Design; 5, Physics of Reactor Design; 6, Geology of Uranium and Thorium; 7, Nuclear Chemistry and the Effects of Irradiation; 8, Production Technology of the Materials Used for Nuclear Energy; 9, Reactor Technology and Chemical Processing; 10, Radioactive Isotopes and Nuclear Radiations in Medicine; 11, Biological Effects of Radiation; 12, Radioactive Isotopes and Ionizing Radiations in Agriculture, Physiology, and Biochemistry; 13, Legal, Administrative, Health and Safety Aspects of Large Scale Use of Nuclear Energy; 14, General Aspects of the Use of Radioactive Isotopes: Dosimetry; 15, Applications of Radioactive Isotopes and Fission Products in Research and Industry; 16, Record of the Conference.

U. S. Nuclear Series

The U. S. Government distributed a set of reference volumes to each delegate at the Geneva Conference on the Peaceful Uses of Atomic Energy. They are now available (clothbound: McGraw-Hill Book Co., Inc., New York; paperbound: Government Printing Office) as a set ($62.00—clothbound prices are given here) or individually.

Following is a brief description of each of the volumes. The three handbooks and the neutron-cross-sections volume were declassified before the conference.

Research Reactors (406 pages, $6.50). Descriptions and design drawings of six U. S. research reactors now in use.

Reactor Handbook: Physics (804 pages, $12.00). Reactor physics, nuclear-design data, including shielding theory and calculating techniques.

Reactor Handbook: Engineering (1088 pages, $15.00). Includes basic reactor systems applicable to power development; summary of experimental reactor designs.

Reactor Handbook: Materials (614 pages, $10.50). Data and background information on fuels, moderators, shielding, structural, and miscellaneous materials.

Neutron Cross Sections (363 pages, $12.00). Recent data compilations.

Chemical Processing and Equipment (316 pages, $6.00). Process and engineering description of separation system; catalog of special equipment for handling radioactive materials.

Nuclear Physics

By ALEX E. S. GREEN (McGraw-Hill Book Co., Inc., New York, 1955, xv + 535 pages, $9.00). Reviewed by W. C. BARBER, High-Energy Physics Laboratory, Stanford University, Stanford, Calif.

This book is an up-to-date treatment of that part of nuclear physics where mesons do not directly manifest themselves. It should be suitable as a text for courses at the beginning graduate level. Problems are provided at the end of each chapter.

The book begins with a review of atomic physics emphasizing how the quantum theory has developed to describe most extranuclear atomic phenomena. The second chapter discusses the characteristics of and evidence for the important static properties of the nucleus, such as charge, mass, spin, and moments. Chapters 3-5 are entitled *Accelerators, Precision Instruments and Methods*, and *Detectors and Nuclear Techniques*. This material, making up 116 pages of the text, provides a good introduction to the practice of experimental nuclear physics, but it is not complete enough to be of great use to workers in the experimental field. Chapters 6 and 7 are devoted to radioactivity and nuclear reactions: both chapters are rather brief, the experimental results being presented with little interpretation. However, the examples illustrating the basic types of reactions are carefully chosen, and the description of the results is made effective by the presentation of diagrams and curves taken from the literature. Chapter 8 is a detailed and authoritative discussion of the systematics of nuclei; section 8-8 is a well-organized summary of the basic nuclear properties that must be inferred to explain experimental data. Chapter 9 contains a discussion of fission and the "liquid-drop" model of the nucleus.

The remainder of the text is concerned chiefly with the interpretation of nuclear phenomena, and an increased background of knowledge is required for understanding the material. Chapter 10, *Quantum Mechanics and the Nucleus*, is not sufficiently complete to serve those who have not previously studied quantum mechanics, but it gives a good review of those features of the theory that are important in understanding the "shell model."

Chapter 11 is devoted to a discussion of how various nuclear models succeed in accounting for the static nuclear properties as well as for the energies and spins of the low-lying excited states. The theories of nuclear decay and nuclear reactions are taken up in Chapters 12 and 13: the treatment of each subject is brief, emphasizing results and conclusions rather than detailed analysis; the organization of the material is good and the important results are stated clearly and accurately. The final chapter is a discussion of nuclear forces centered about information provided by studies of the neutron-proton and proton-proton systems; a few paragraphs on mesons serve as a reminder and warning that the story is far from complete.

In the reviewer's opinion the book is accurate and comprehensive; it emphasizes the important subjects and is well written. One possible disadvantage is that the scope of the book is so large that explanations of the material are necessarily often brief and incomplete; this lack is to some extent overcome by the extensive and well chosen references to original work.

Beta- and Gamma-Ray Spectroscopy

Edited by KAI SIEGBAHN (Interscience Publishers, Inc., New York, 1955, xxiii + 959 pages, $20.00). Reviewed by FRANZ R. METZGER,

Bartol Research Foundation of the Franklin Institute, Swarthmore, Pa.

This book consists of 42 review articles covering practically every aspect of one of the most important branches of nuclear physics. The individual contributions, with very few exceptions, are well presented, authoritative and up-to-date. Most of them are of necessity short, but compensate for this with a large number of references to more elaborate discussions and to the original literature. The references are conveniently arranged as footnotes. An appendix contains many very useful numerical tables.

The large number of contributors brings with it a certain lack of continuity in the presentation and an accidental distribution of emphasis. While, for example, the angular correlation of nuclear radiations is discussed at great length, the experimental methods for the determination of internal conversion coefficients are not reviewed in a special chapter, but are briefly mentioned in three different sections. Similarly, there exists in this book dealing with gamma-ray spectroscopy no paper discussing the methods used for the determination of gamma-ray energies. The information has to be gathered from many different chapters. While this fact might not trouble the worker who is familiar with the field, it reduces considerably the usefulness of the book for the newcomer. A more detailed subject index would improve things and could be incorporated without increasing the size of the book by sacrificing the author index.

After two short papers on the interaction of electrons and of gamma rays with matter, a discussion of the theory and the design of beta-ray spectrometers familiarizes the reader with the many instruments now in use and introduces him to the problems that can be tackled with these spectrometers. The precision instrument in the gamma-ray field, the bent-crystal spectrometer, is described in the next chapter. Two separate papers are devoted to the less ambitious, but more effective, techniques of the scintillation counter and the proportional counter.

The Geiger counter is discussed to some extent in the chapter on the measurement of disintegration rates and in a section on special beta spectrometer techniques. Unfortunately, the Geiger counter also forms the basis for the discussion of the coincidence method although in this field, more than anywhere else, the obvious advan-

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tages of the scintillation counter have rendered the Geiger counter obsolete. Information concerning the use of the fast and highly efficient scintillation counters in coincidence experiments is found in the chapter on the scintillation method and in the discussion of the measurement of lifetimes with the delayed-coincidence method. A guide to the investigation of decay schemes and a special chapter containing a detailed discussion of a few typical decay schemes provide ample introduction to the beginner in this field.

The theory of beta decay is presented in a very appealing way that will also satisfy the experimentalist. An excellent summary on the experimental evidence on shapes of beta spectra and a status report on the tedious neutrino-recoil experiments nicely round out the discussion on beta decay.

The gamma-ray transitions are introduced with a chapter on the theory of multipole radiation. It is followed by a summary of the theory of internal conversion. To all those engaged in the study of the multipole character of gamma-ray transitions, this chapter will prove very valuable. It presents in many figures and in tables in the appendix the results of recent calculations by Rose and coworkers of *K*- and *L*-shell conversion coefficients, which so far have only been privately circulated.

Many readers will also appreciate the inclusion of discussions of the shell model and of the collective model as well as papers on classification of beta transitions and of nuclear isomers.

The development of the scintillation counter has made possible the detailed study of many phenomena that had escaped detection or had been very difficult to tackle in a quantitative way with Geiger counters. Probably the most important of the newly opened fields is the study of angular correlations, which is discussed in a very thorough article. Many other applications of the scintillation counter, e.g., the double Compton effect, internal bremsstrahlung, internal pair formation, double beta decay, annihilation of positrons, positronium, resonance fluorescence, are presented in short papers. These contributions are especially welcome in those cases in which no recent review articles are available.

A summary on beta- and gamma-transitions in heavy radio-elements indicates a revival of interest in this part of the periodic table.

Finally two papers on the gamma radiation from charged-particle reactions and on neutron-capture gamma rays discuss the methods used for the detection of high-energy gamma rays and present the data available.

In conclusion, we expect that the newcomer, although sometimes frustrated in his attempt to locate a certain subject, will find that many of the reviews give him a good impression of what to expect from a particular field. The experienced worker will appreciate the wealth of references and will consider the book as a handy collection of review articles, which otherwise are dispersed in many different publications. While the book should be in the library of every institution working in the field, the high cost will deter many individual workers from purchasing it.

Analysis of Feedback Control Systems

By ROBERT A. BRUNS and ROBERT M. SAUNDERS (McGraw-Hill Book Co., Inc., New York, 1955, xv + 383 pages, $7.50). Reviewed by J. R. BURNETT, School of Electrical Engineering, Purdue University, Lafayette, Ind.

This is one of the many recent books on the subject of servomechanism theory. It differs from the others primarily in organization and the weight given the subject of components. The subjects treated by chapters are in the following order: mechanical systems; electric actuators; hydraulic elements; pneumatic elements; electric-circuit elements; electronic amplifiers; magnetic amplifiers; dynamoelectric amplifiers; transducers; reference standards; specifications and stability; block diagrams and network reduction; experimental means of obtaining transfer functions; transient response from frequency response data; nonlinear systems; and discontinuous systems. There are 383 pages of which 208 are devoted to components and the remainder to feedback theory.

The organization of the book is quite different from other servo books. The most striking feature is the inclusion of the component data at the first of the book before the theory. This leaves one in the position of deriving the transfer function of a component but without adequately understanding its use. Where the use is clarified, attention must be directed to an unread chapter to obtain the theory. This leaves the reader in the position of having to read the book as a whole and not chapter by chapter starting from the beginning. The rigor of the book is confined to the appendix, which is concerned with complex variable

theory and the proof of the Nyquist stability criteria.

The lack of Laplace transform theory also presents some interesting problems to the reader. For instance on p. 95 the transfer function of a transmission-line type of delay appears without any justification. On p. 50 the frequency domain form of time differentials also suddenly appears; however, in this case there is a reference given. The subject of poles and zeros is avoided until there is no recourse. They are mentioned first in the section of Nyquist stability concepts, but are not explained until a later chapter on root locus. Even then there is no explanation as to how the quantity $j\omega$ suddenly appears with a real and an imaginary part.

There are many inconsistencies within the book. For instance, the preface points out that most engineers and students are familiar with steady-state sinusoidal concepts, and presumably these are the people who will read the book; then in the electric-circuit-element chapter space is allocated to defining impedances of the electrical elements, but no mention is made of Kirchoff's laws. Also in the preface it is pointed out that the analysis of feedback systems has evolved from the art stage to the scientific, but then in the block diagram section attention is called to the new type of creative art, reshaping transfer-function plots.

There are many good features of the book. In a sense, the lack of the conventional Laplace-transform introduction is a good innovation because in many servo books it is actually not used after the introductory chapters. It does cause some troubles when root locus plots are introduced. For instance, transients are formed from the differential-equation approach. The introductory chapters on components have some good features as regards units, computations of inertia, and similar topics from mechanics. There are useful tables of asymptotic plots, transfer functions, and the corresponding networks. There are also useful tables of block-diagram-reduction techniques. There are many excellent problems and numerical examples. The experimental techniques chapter is quite good.

Mathematical approaches to the problems of feedback engineering have been omitted, but still this book has merit as an introductory, survey medium into servomechanisms.

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ALSO OF NOTE

World Development of Atomic Energy. This report of the nonmilitary atomic-energy activities of 32 countries is based for the most part on a survey conducted by the Atomic Industrial Forum, Inc. A supplementary section describes the U. S. bilateral-agreements program, including verbatim reproductions of the agreements with Turkey, Belgium, Canada, and the United Kingdom. *Atomic Industrial Forum, Inc., 260 Madison Ave., New York 16, N. Y., $5.00.*

Atomic Energy in Pharmacology: Industrial and Legal Aspects. This report describes domestic and foreign pharmacological investigations with carbon-14 and related literature references. Government regulation of radioisotope use is discussed. *New York Committee on Atomic Information, Inc., 61 Broadway (Suite 704), New York 6, N. Y.*

Recommended Safe Practice for Laboratories Handling Radioactive Materials. These recommendations were prepared by the NFPA Committee on Atomic Energy and adopted by the NFPA May 17, 1955. They are mainly concerned with laboratories handling small quantities of radioisotopes (1 curie or less); reactors and accelerators are mentioned briefly. *National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass., $0.50.*

High-Energy Nuclear Physics. The proceedings of the Fifth Annual Rochester Conference (1955) contains seven main sections: Low Energy Pion Phenomena, High Energy Pion Phenomena, Theoretical Session, Elementary Particles—Experimental, Elementary Particles, Elastic Scattering of Nucleons, and Accelerator Physics. A discussion of the Conference was presented in NUCLEONICS (May, 1955, p. 34). *Interscience Publishers, Inc., 250 Fifth Ave., New York, N. Y., $2.50.*

Atomic Energy and New England. This booklet is the report of the New England Committee on Atomic Energy to the New England Governors' Conference. It presents the conclusions of a year's study of the significance of atomic-energy development to New England and recommendations to government, industry, and educational institutions. Among the recommendations are: appointment of a coordinator in each state; establishment of an AEC

administrative office and library of classified information in New England; and construction of four university research reactors and a high-flux materials-testing reactor. *New England Committee on Atomic Energy, 50 Memorial Drive, Cambridge, Mass., $1.00.*

First Temple of the Atom. This booklet describes and presents illustrations of the Raleigh research reactor of the University of North Carolina. *Physics Dept., North Carolina State College, Raleigh, N. C., $0.50.*

Chart of Atomic Nuclei. Prepared by M. L. Pool and D. N. Kundu, this 46 × 34-in. chart presents nuclear spin, magnetic moment, delayed-neutron emitters, parity, quadrupole moment, and magic numbers. Stable nuclides are in green, unstable in red. *Long's College Book Co., Columbus 10, Ohio, $12.50.*

World Map. This world map measures 12 square feet. It is in color and on heavy-duty stock. *Radak Co., 505 Fifth Ave., New York 17, N. Y., $1.00.*

Translation Monthly. This 8-page monthly bibliography lists alphabetically by author current additions to the Special Libraries Association Translation Pool. The translations are from all languages except Russian. Subscriptions are accepted only for a calendar year beginning with Vol. 1, No. 1, Jan. '55. *SLA Translation Pool, The John Crerar Library, 86 E. Randolph St., Chicago 1, Ill., $5.00/yr.*

Reference Tables for Thermocouples (NBS Circular 561). Superseding National Bureau of Standards Circular 508, this volume gives reference tables for Pt-Pt (13% Rh), chromel-alumel, Fe-constantan (modified 1913), Cu-constantan, and chromel-constantan thermocouples with temperature in °C and °F and emf in millivolts. The tables are based on the absolute electrical units and the International Temperature Scale of 1948. *Government Printing Office, Washington 25, D. C., $.50.*

Report of the Conference on Defects in Crystalline Solids. Held at the University of Bristol, July, 1954, the conference was especially concerned with dislocations and point defects, and particularly experimental methods. Much attention is given to the magnetic resonance methods for investigation. *The Physical Society, 1 Lowther Gardens, Prince Consort Rd., London S.W.7, England, 40s.*

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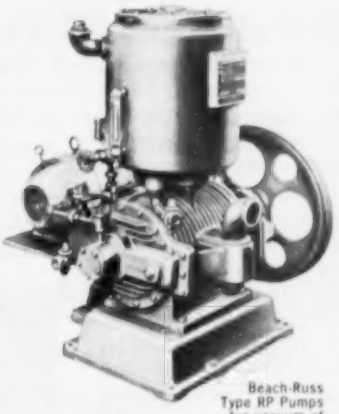

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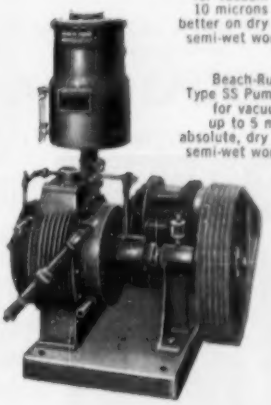

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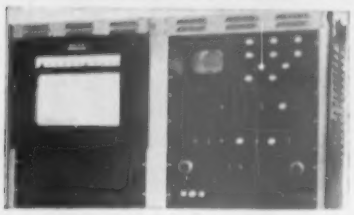
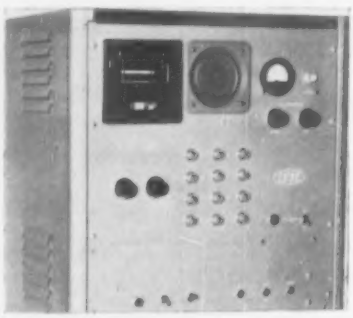
RADIATION DETECTORS AND ACCESSORIES



Multichannel Analyzers

Based on Argonne's model 101 these new analyzers (Model 3301 and 3300) use magnetic-core memories. Data accumulation is in decimal mode with continuous linear readout on CRT and decimal printer or graphical record (appropriate sections shown below, left). Linearity is 0.2%. —Radiation Instrument Development Laboratory, 2337 W. 67 St., Chicago 36, Ill.



10-Mc Scalers

Including high-voltage supply, 10-Mc-bandwidth preamplifier, and pulse-height discriminator, model 4104 (binary scale-of-4,096) and model 4124 (decade scale of 1,000) are specially designed for high-speed counting.—Electrical and Physical Instrument Corp., 25 W. 43 St., New York 36, N. Y.

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Collimated counter. Model CS-100 scintillation counter affords variable collimation, comes equipped with 1 × 1-in. NaI crystal and photomultiplier. —NRD Instrument Co., 6425 Etzel Ave., St. Louis 14, Mo.

Stable HV Supply

Featuring 3-ppm per volt stability against line-voltage variations and 2.5-ppm/milliamp regulation, the N401 high-voltage supply provides 500–1,800 volts at up to 5 milliamp. It uses 21 ultrastable 85A2 regulators. —Hamner Electronics Co., Inc., Box 531, Princeton, N. J.

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Products Index

Radiation Detectors and Accessories 96
Controllers and Recorders ... 97
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Literature Available 99

Ratemeter. Type 12112 combines two six-stage decade counters; one measures cycles of a built-in tuning fork, other counts unknown frequency or pulse source.—Research and Control Instruments Division, North American Philips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Counter-timer. DS-1700 counts from 40 μsec to 100,000 sec with 100-kc crystal oscillator; it can also count unknown against this standard.—Detectron Corp., North Hollywood, Calif.

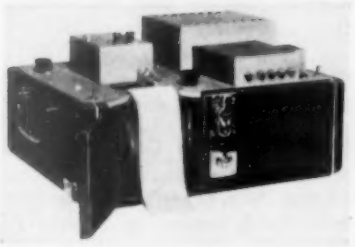
Portable counter. Model 521A Industrial Counter provides direct reading of frequencies from 1 cps to 120 kc based on 100-kc crystal standard and 1 or $\frac{1}{10}$-sec count.—Hewlett-Packard Co., Dept. P, 395 Page Mill Rd., Palo Alto, Calif.

New Dekatron. GS12D is self-indicating scale-of-12 cold-cathode counting tube with all 12 cathodes brought out to pins in base. Counting rate is to 4,000 cps.—Atomic Instrument Co., 84 Mass. Ave., Cambridge 39, Mass.

Transistorized HV supply. Power packs provide from 200–1,500 volts at 50 μamp to over 4,000 volts at 1 μamp from single 1.5-volt flashlight battery.—Universal Atomics Inc., 19 E. 48 St., New York, N. Y.

Counter-converter. New unit provides two 3-digit or single 6-digit counters plus converter assembly providing contact closures to operate IBM-type Summary Punches.—Harper Engineering Co., 2330 Michigan Ave., Santa Monica, Calif.

CONTROLLERS AND RECORDERS



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pends only on the taper of the input potentiometer, so that many functions can be recorded. Instrument is particularly suited for reverberation, sound intensity, vibration or sound-decay measurements—Sound Apparatus Co., Stirling, N. J.

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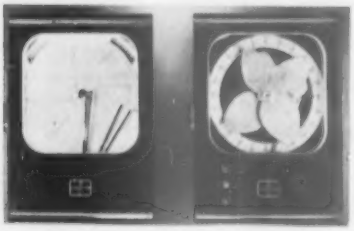

Two-Pen, Two-Cam Controller

Cycle controller combined with a two pen, two-cam controller in a two-case unit achieves fluctuation of one variable while another is going through a different fluctuation at a sychronized time. The cams are cut individually and locked together in desired time relationship. Variety of program controllers are available. The two-pen recorder makes two records at same time on 12-in. round chart.—The Bristol Co., Waterbury 20, Conn.

Plug-In Millivolt Controller

With three control forms—on-off, two position, three position—mv controller is housed in horizontal case, 19 × 6 × 10¾-in. deep. Neutral zone is adjustable from 0–100% of full scale (wide zone) or from 0–10% of full scale (narrow zone). Calibrated accuracy of instrument is ±¾% of full scale.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Sensitive Transducer

Electromagnetic transducer in use at British U-diffusion plants is independent of supply voltage and frequency variations. Mechanical displacements <0.001 in. are measurable. Bridge circuit uses two resistors and two induction coils. Transducer can be converted to pressure gage by adding diaphragm or Bourdon tube.—General Electric Co., Ltd., Magnet House, Kingsway, W. C. 2, London, England.

Constant-Flow Device

Set rate of flow for hot or cold water from 0.2–8 gal/min is delivered within 10% for line pressures from 10–150 psi by the Mensurflo control. Pressure flexes Neoprene diaphragm into grooves and holes of brass orifice plate to regulate flow. Pipe sizes are ¼, ⅜ and ½ in.—Hays Manufacturing Co., Dept. 238, West 12 St., Erie, Pa.

Miniature Strip-Chart Recorder

Null-balance recorder uses 5-in. translucent paper. Pen speed is 0.5-sec full scale, and accuracy is 0.25%. Input sensitivities are 10, 50, 100 or 500 mv, d-c. Chart speeds are adjustable for 4, 10 or 20 in./hr. Recorder will mount in standard 9⅝ × 19 in. relay rack panel.—Westronics, Inc., 3605 McCart St., Fort Worth, Tex.

•

Inkless recorder. As many as 30 channels can be recorded on one chart inklessly. Also available is model MR contact meter with remote reset feature. Available in many ratings. —Larson Instrument Co., 24 Orchard St., Tarrytown, N. Y.

INDUSTRY NOTES

▶**Paterson Research Co.,** 132 Beckwith Ave., Paterson, N. J., has been formed to consult in all aspects of atomic energy.

▶**American Electronics, Inc.,** of Los Angeles, has purchased **R-C Scientific Instrument Co.,** Playa Del Rey, Calif., designers and manufacturers of radiation measurement apparatus, and will operate it as a wholly-owned subsidiary, **Reed-Curtis Nuclear Industries.**

▶**Industrial Development Laboratories,** 17 Pollock Ave., Jersey City, N. J., has purchased manufacturing rights to the SM-3A scintillation survey meter from **Nuclear Research Corp.,** Southampton, Pa., and will produce and market it henceforth.

▶**Nuclear Development Associates** has changed its name to **Nuclear Development Corporation of America** retaining the familiar NDA. The firm has moved to new quarters at **5 New St., White Plains, N. Y.,** and is developing a Nuclear Experimental Station near Pawling, N. Y.

▶**High Voltage Engineering Corp.** has opened a West Coast office at 1644 Grove St., Berkeley, Calif., managed by **George C. McFarland,** formerly of UCRL.

▶**Ketay Limited** has been formed by **Norden-Ketay Corp.** and **Plessey Co.,** Ltd. to design, develop, and manufacture servomechanisms in England.

▶**Hamner Electronics Co., Inc.,** Box 531, Princeton, N. J., has been formed by Princeton scientists to develop, manufacture, and market advanced-design instruments.

▶**Jordan Electronics, Inc.,** manufacturers of radiation monitoring instruments, have moved to new 12,000-sq-ft facilities at **3025 W. Mission Rd., Alhambra, Calif.**

▶**Bell Aircraft Corp.** has retained **Nuclear Science and Engineering Corp.,** to render assistance and advice. **Eugene Zuckert,** former AEC Commissioner, will be active in management-consulting phases.

▶**Ford Instrument Co.,** division of Sperry Rand Corp., has opened an office at **260 S. Beverly Drive, Beverly Hills, Calif.** headed by **Edward F. Manion.**

▶**Consolidated Vacuum Corp.,** subsidiary of Consolidated Engineering Corp., has concluded an agreement to manufacture and market high-vacuum distillation apparatus developed by the **Distillation Products Indus-**

tries, Division of Eastman Kodak Co.

▶**Perkin-Elmer Corp.,** Norwalk, Conn., has formed a new subsidiary, **Nuclear Magnetics Corp.,** to market the nuclear magnetic resonance equipment developed by the **Laboratory for Electronics,** Boston, Mass.

▶**Crane Packing Co.,** has broken ground for a 46,500-sq-ft building to include laboratory facilities for developing products for the nuclear field.

▶**Varian Associates,** will add 25,000 sq ft to its Palo Alto, Calif. plant to provide more space for developing nuclear magnetic resonance equipment.

LITERATURE AVAILABLE

Research reactors. Bulletin GEA-6326 describes 30-kw heterogeneous NTR, 50-kw water boiler (WBR), and 1-Mw swimming pool (SPR). 8 p.—General Electric Apparatus Sales Div., Schenectady 5, N. Y.

Reactor instruments. Count, period, and safety amplifiers, power supplies, detectors, and recorders are listed. 8 p.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia, Pa.

Dense metal. Fansteel 77, machinable W-Cu-Ni alloy used in shields, is described in new booklet. 16 p.—Fansteel Metallurgical Corp., North Chicago, Ill.

Materials production. Brochure describes nuclear-materials production, equipment for metals production, high-vacuum technology, and nuclear process engineering. 6 p.—National Research Corp., 70 Memorial Dr., Cambridge 42, Mass.

Nuclear instruments. Catalog supplement No. 4 lists new counters, pulse-height analyzers, apparatus for brain-tumor localization, etc. 44 p.—Atomic Instrument Co., 84 Massachusetts Ave., Cambridge 39, Mass.

Radiation measuring equipment. Catalog P covers complete line for medical, industrial, and research applications. 48 p.—Nuclear Chicago, 229 W. Erie St., Chicago 10, Ill.

Radiopharmaceuticals. Price list and progress report on new radioisotope techniques. 24 p.—Abbott Laboratories, North Chicago, Ill.

Auto radiation detector. RN-755 describes how automobile radio can be used as radioactivity detector sim-

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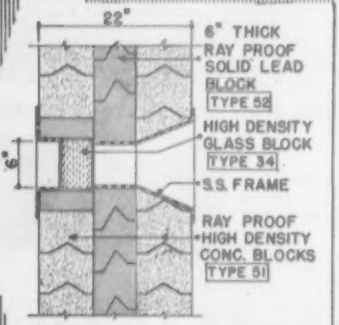

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ply by adding G-M tube and a few electronic components.—International Rectifier Corp., 1521 E. Grand Ave., El Segundo, Calif.

Mutual fund. Three publications are available: portfolio, with map, of fund holdings; chart of reactor types; and management brochure.—Atomic Development Mutual Fund, Inc., 1033 30th St., N. W., Washington 7, D. C.

Pocket battery monitor. Folder gives data on PW-4010 G-M tube monitor. 4 p.—North American Philips Co., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Analyzer comparison. RIDL114-5 cross-reference sheet lists features of single-channel pulse-height analyzers to aid selection.—Radiation Instrument Development Laboratory, 2337 W. 67 St., Chicago 36, Ill.

Indicating titrator. Bulletin 615 describes high-sensitivity wide-range instrument for nonaqueous titrations. 4 p.—Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.

Proportioning pumps. Applications memo BIF M37 shows use of Adjust-O-Feeder pumps in conditioning boiler water. 2 p.—Proportioneers, Inc., 345 Harris Ave., Providence, R. I.

Optical bench. Precision universal instrument bench and over 50 available components provide for mock-ups of instruments and testing. 20 p.—Meyer-Opticraft, Inc., 39 W. 60 St., New York 23, N. Y.

Recording charts. Sixteen technical notes list special recording papers including heat- and electro-sensitive types.—Technical Charts Inc., 189 Van Rensselaer St., Buffalo 10, N. Y.

Apparatus, mercury. Catalog 54 lists glassworking gear and mercury with related cleaning and vapor-detecting equipment.—Bethlehem Apparatus Co., Inc., Front and Depot Sts., Hellertown, Pa.

Magnesia-insulated conductors. High-temperature, swaged, magnesia-insulated conductors are described in bulletin 6A.—Aero Research Instrument Co., 1040 Grand Ave., Chicago 22, Ill.

Engineering services. Engineering and construction services available are explained in bulletin 2505.—Chemical Plants Div., Blaw-Knox Co., Farmers Bank Building, Pittsburgh 30, Pa.

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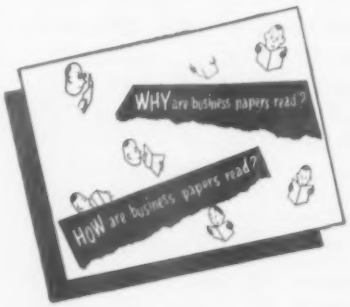

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LETTERS

Radiation-Liability Insurance

In the following letter, Mr. Stratton is commenting on NUCLEONICS' *report (July '55, p. 13) of a policy issued to Technical Operations, Inc., by Indemnity Insurance Co. of North America. Indicative of Travelers' activity in the nuclear power field is a policy issued July 18 for General Electric's West Milton power station.*

DEAR SIR:

. . . I feel duty bound to have you know that the policy issued was not exceptional in any way. My own company and several others have absorbed such risks regularly for a number of years, not considering such forms of insurance to be at all spectacular nor meriting front page coverage. Possibly we were wrong and should have advertised.

The main point, however, is that this type of coverage and the inclusion under it of radioactive products is not new.

—REUEL C. STRATTON
The Travelers
Engineering and Loss Control Division
Hartford, Connecticut

Monitoring with Commercial Film

DEAR SIR:

Pertinent to "Disaster Monitoring with Amateur and Commercial Photographic Films" (NU, Aug. '55, p. 40), in 1952 we at Polaroid Corp. explained how to use the film in our camera as a disaster monitor for γ-radiation, permitting 1-min development without need for darkroom or special chemicals (U. S. Patent 2,705,757).

A tab of fluorescent X-ray screen is clipped inside the camera just to one side of the lens, close to the negative film when the camera is in normal (closed) state. With 0.1–2 r, the film as a whole is practically unaffected, but the tab fluoresces just enough to produce a "fogged" area on the film; 2–40 r produces varying degrees of fogging by direct action on the film. A density step wedge gives rough dose estimation. The method does not interfere with normal camera use.

—WILLIAM A. SHURCLIFF
Research Department
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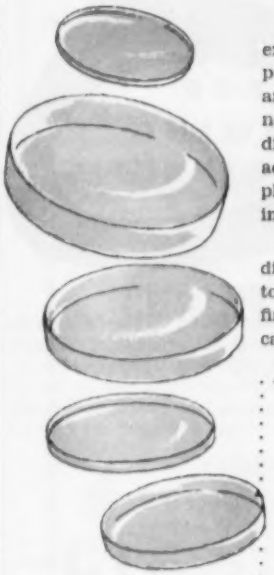

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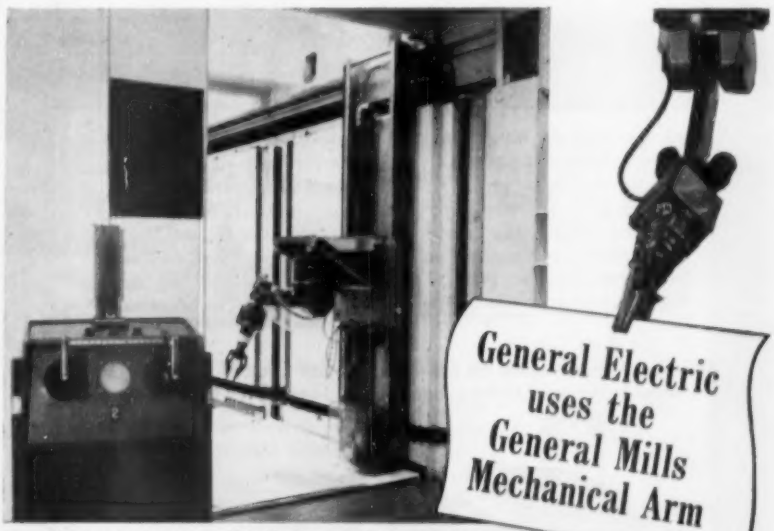

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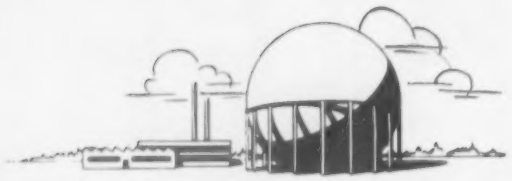
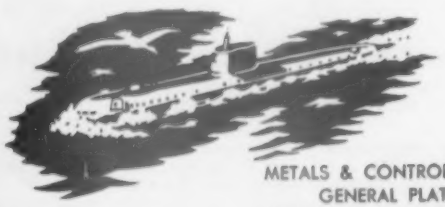


Fuel Element Materials fabricated by the General Plate Division now being used in the production of power from the atom.



METALS & CONTROLS CORPORATION
GENERAL PLATE DIVISION
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NEWSMAKERS

Clarence E. Larson, director of Oak Ridge National Laboratory, has been appointed vice president in charge of research for National Carbon Company. **Alvin M. Weinberg,** research director, becomes director of ORNL, and **John A. Swartout,** assistant research director, becomes deputy laboratory director.

Alexander Squire, former manager of the Apparatus Dept. of the Atomic Power Div. of Westinghouse Electric Corp., has been appointed manager of the company's submarine fleet reactor project.

Corbin Allardice has resigned as executive director of the Joint Congressional Committee on Atomic Energy to accept the position of atomic energy adviser to the International Bank for Reconstruction and Development.

Leonard Smiley has been appointed manager of technical coordination in the Atomic Energy Div. of Sylvania Electric Products, Inc.

C. Burton Clark heads Harbison-Walker Refractories Co.'s new nuclear research unit in Pittsburgh to investigate possibilities of new type of refractory construction materials.

Three new managers have been named in the Atomic Power Equipment Dept. of General Electric Co.'s Atomic Products Div.: **Raymond C. Freeman,** manager of newly established engineering section and acting manager of employee relations; **Louis E. Newman,** manager of newly established marine propulsion study; **John M. Hobbs,** manager of manufacturing. **Paul R. McMurray,** superintendent in the reactor section of the Hanford manufacturing dept., has been named manager of the radiological engineering section of General Electric's radiological sciences dept. He succeeds **J. M. Smith, Jr.,** who will be in charge of radiological engineering for GE's Commonwealth Edison atomic power reactor project. **J. Emmett Maider,** former manager of manufacturing at Hanford, assumes managership of the Commonwealth Edison Chicago nuclear power plant project in the General Electric Atomic Products Div. in Schenectady.

Harry Soodak has taken leave from the College of the City of New York to be head of the reactor physics group of Nuclear Development Corp. of America.

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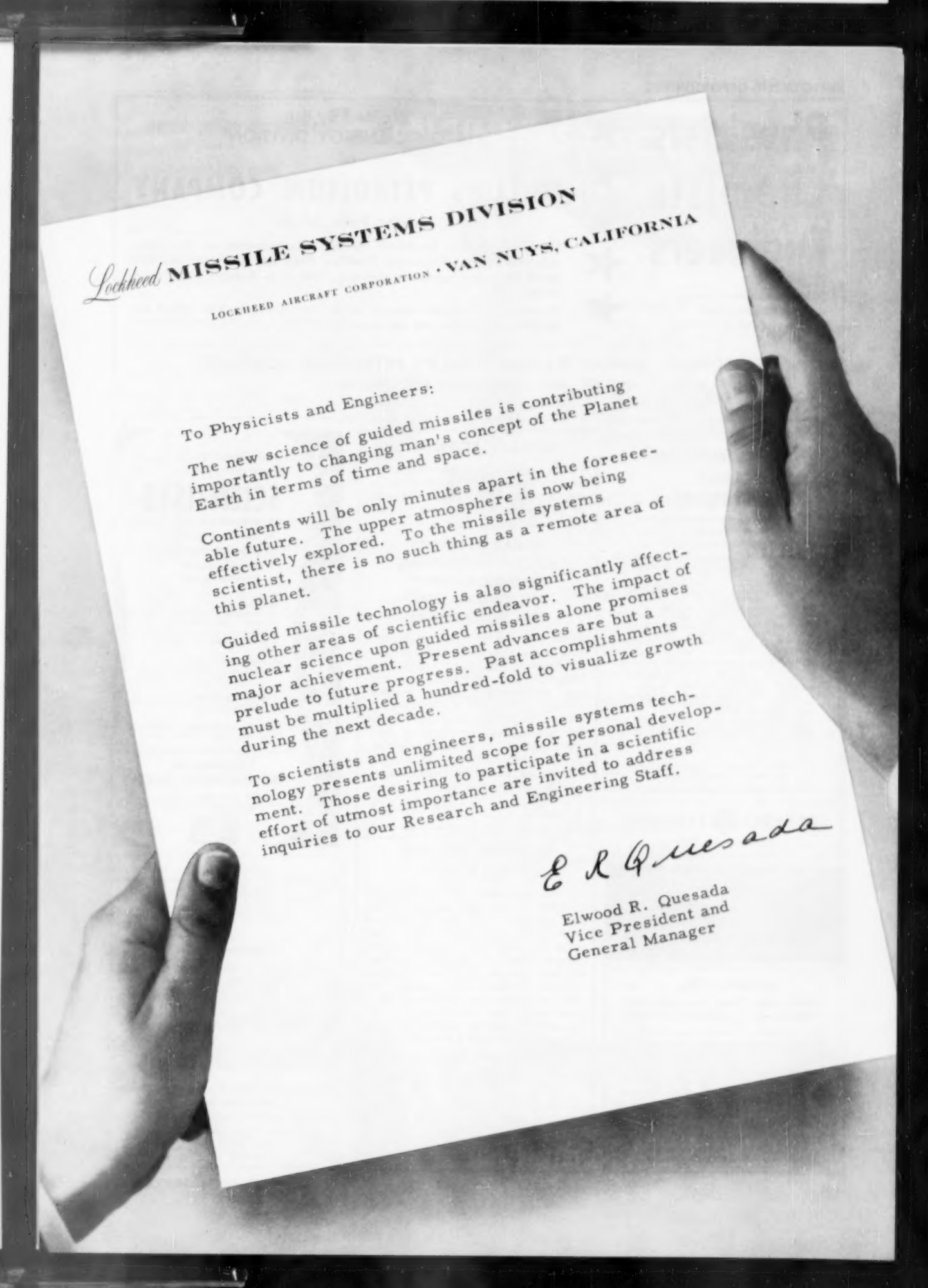

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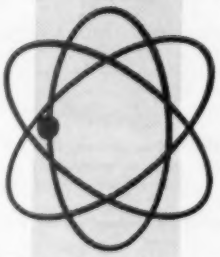

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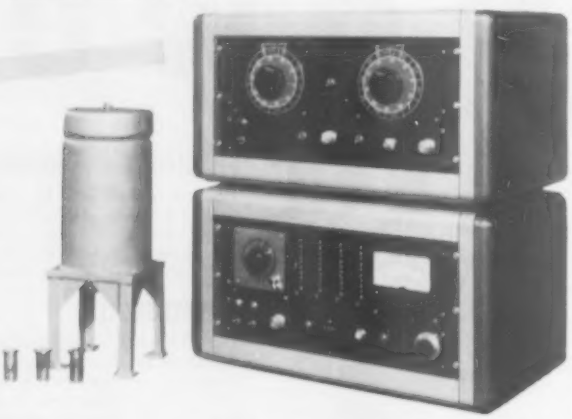

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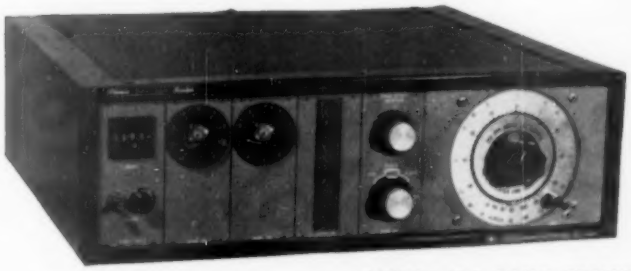
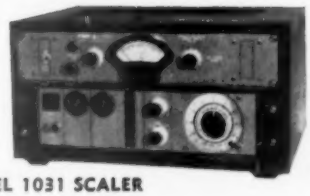


MODEL 131 BASIC SCALER



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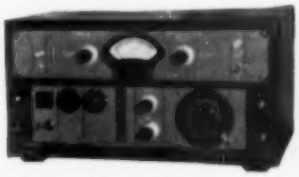

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